NATIONAL CRITICAL MATERIALS COUNCIL

HEARING

BEFORE THE

SUBCOMMITTEE ON TRANSPORTATION AVIATION AND MATERIALS

OF THE

COMMITTEE ON SCIENCE AND TECHNOLOGY HOUSE OF REPRESENTATIVES

NINETY-NINTH CONGRESS

SECOND SESSION

SEPTEMBER 17, 1986

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*Ranking Republican Member.
**Serving on Committee on the Budget for 99th Congress.

CONTENTS

WITNESSES

September 17, 1986:

	Page
Thomas Moore, Acting Chairman, National Critical Materials Council, accompanied by Brian Benson, Executive Director; and John Morgan, chief staff officer, Bureau of Mines	5
Peter D. Blair, program manager, Energy and Materials Program, Office of Technology Assessment, accompanied by Gregory Eyring, project director, Energy and Materials Program	33
James Ford, president, Federation of Materials Societies; and Jonathan W. Hinton, chairman, Government Affairs Committee, U.S. Advanced Ceramics Association, accompanied by John A. Coppola, manager, Advanced Programs, Structural Ceramics Division, Standard Oil Engineered Materials Co	67

NATIONAL CRITICAL MATERIALS COUNCIL

WEDNESDAY, SEPTEMBER 17, 1986

HOUSE OF REPRESENTATIVES,
COMMITTEE ON SCIENCE AND TECHNOLOGY,
SUBCOMMITTEE ON TRANSPORTATION,
AVIATION, AND MATERIALS,
Washington, DC.

The subcommittee met, pursuant to call, at 9:35 a.m., in room 2318, Rayburn House Office Building, Hon. George E. Brown, Jr. (chairman of the subcommittee) presiding.

Mr. BROWN. The subcommittee will come to order.

We will start with some opening statements.

The National Critical Materials Council was established by title II of the Critical Materials Act of 1984, Public Law 98-373, a law with strong bipartisan support of the full Congress. Despite that strong Congressional support and despite the importance of this issue, little or nothing has been done to implement the law. The President waited a full 16 months before announcing the appointment of its three members. Within 2 months of their appointment, two of the members, including the Chairman, had resigned, leaving the Council in limbo. The law called for a number of specific reports and actions to be taken by the Council, including a mandated long-range assessment due in April of last year. Aside from one public hearing held last January, I am unaware of any discernible activity of the Council.

Meanwhile, while other nations, including Japan and our Western allies, have moved ahead aggressively in formulating and implementing strong national programs in basic and advanced materials, we continue conducting business as usual in a disorganized, uncoordinated, and shortsighted manner. As noted in the OTA report, which we will be hearing about later, a number of these advanced materials represent an opportunity as well as a challenge for the United States. Unless this situation changes, the United States will lose this opportunity, an opportunity that translates into hundreds of thousands of jobs and tens of billions of dollars.

The administration's less than enthusiastic response to the Council, the main instrument for Government action in this area, raises a number of questions: What, if anything, is the agenda of the Council? When will the mandated assessments and actions be carried out? What more needs to be done to ensure movement in this area?

In closing, I would note that almost a year ago a similar hearing was held in which similar questions concerning critical materials were raised. Astonishingly enough, the President announced ap-

pointment of the Council within weeks of that hearing. This week, I understand that the current vacancies on the Council are being filled. As much as I am pleased that our hearings have proven successful in prompting Presidential action on this issue, it would be nice if these actions were more self-initiated.

I am looking forward to hearing further from our administration witnesses as well as those from the Office of Technology Assessment and the distinguished representatives of industry who are here this morning.

Lest you think my statement is too strong, I would like to insert at this point the statement of Mr. Harry Reid, another member of the committee, which I won't read, but I assure you that it's even stronger, and now I'll recognize our distinguished ranking minority member, Mr. Lewis.

[The prepared statement of Mr. Reid follows:]

STATEMENT OF HONORABLE HARRY M. REID

SEPTEMBER 17, 1986

As a representative from a state where mining is a major sector of the economy I am interested in establishing policies to keep the domestic mining industry viable and competitive. As a member of the House Foreign Affairs Committee I am interested in establishing policies to insure adequate supplies of critical materials during wartime. On July 31, 1984, when Congress passed--and the President signed into law--the Critical Materials Act, it appeared the Administration was willing to cooperate in the establishment of a critical materials policy with wide-spread support. However, the subsequent actions of the Administration belie any interest in establishing any critical materials policy at all.

The administration has a sad record of achievement when it comes to the support of the domestic mining industry and the establishment of a critical materials policy. About a year and a half ago I had the privilege of chairing hearings held by this Subcommittee on the reauthorization of the Bureau of Mines. At that time, the Subcommittee learned of Administration attempts to phase-out the Bureau. This, despite the fact the Bureau of Mines, through the Mining and Mineral Resources Research Institute, had established 31 successful partnerships between State Universities, the federal government and private industry. These partnerships carry-out basic research into fields as diverse as mine safety, environmental protection, substitution of materials, increasing productivity, etc. This basic research and development, which routinely receives government support in allied countries, is simply beyond the resources of the domestic mining industry to undertake on its own.

Looking at the Administration's budget proposal for fiscal year 1987, it is clear the assault upon the Bureau, and in particular its R&D budget, will continue.

All parties have agreed to the importance of stockpiling critical materials for national defense purposes. Or at least it seemed at first. In July 1985, the Administration apparently concluded there is no longer a need to stockpile platinum group metals (PGMs) and recommended declaring the PGM stockpile excess and selling it off. The reasons for the decision have yet to be made public but must be quite compelling in light of the argument conditions in South Africa make for continuing to stockpile PGMs.

For over two years now, the National Critical Materials Council was supposed to be establishing critical materials policy as per the provisions of Public Law 98-373. In two years the Council could easily have identified and recommended many detailed policy options. Several options come immediately to mind: using our negotiating strength to open foreign markets; restricting our own markets; increasing the federal commitment to material R&D, I could list ideas all day. But my job is to evaluate the options the Council develops, assess their feasibility, and gather the votes necessary to implement policy recommendations.

I hope during today's hearing the Subcommittee will learn the intention of the Administration regarding the future of the National Critical Materials Council. The Members of the Subcommittee would prefer to cooperate with the administration in developing a critical materials policy. But as the witness list shows, Congress can go to other sources for policy recommendations if it must.

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Mr. LEWIS. Thank you, Mr. Chairman.

Two years ago, this subcommittee was instrumental in getting the Critical Materials Act passed. This act has wide support from industry and academia. Although the administration generally opposed this legislation, it was not without its supporters in the administration as well.

Now, 2 years later, we're still waiting to see if we did the right thing. Can a highly placed council within the administration provide the much needed leadership in establishing some long-range goals for developing minerals and materials independence? Can the Critical Materials Council, which is charged with providing this Nation with a comprehensive, coordinated materials policy, make a difference, or will this be another needless bureaucracy needing funding each year, as its critics claim?

We won't know the answers to these questions until the administration makes a good faith effort to implement this law and support the Council.

I also was very pleased to hear that the President has just appointed two additional members to the Council, including a permanent Chairman, Mr. Hodel. I hope this means we will now see progress in the implementation of this act.

Thank you, Mr. Chairman.

Mr. BROWN. Thank you very much, Mr. Lewis.

Gentlemen, of course, none of these remarks are intended to reflect upon your own posture, which we have the highest respect for, needless to say. I do hope we won't have to have quarterly hearings on this subject in order to move the program along a little more rapidly than it has been in the past.

We are very pleased to have Dr. Moore as our first witness, who has been serving valiantly as the Acting Chairman and only member of the Council now for a number of months, and we look forward to your testimony.

STATEMENT OF THOMAS MOORE, ACTING CHAIRMAN, NATIONAL CRITICAL MATERIALS COUNCIL, ACCOMPANIED BY BRIEN BENSON, EXECUTIVE DIRECTOR; AND JOHN MORGAN, CHIEF STAFF OFFICER, BUREAU OF MINES

Dr. MOORE. Thank you, Mr. Chairman.

I would like to first introduce Brien Benson, who is the Executive Director of the National Critical Materials Council, who is here on my right, and with me also, Dr. John Morgan, Chief Staff Officer of the Bureau of Mines, right behind me.

Let me say that I am very pleased with the announcement of Secretary Don Hodel and Bill Martin to the Council. Secretary Hodel sends his personal greetings to you, Congressman Brown, and he says to convey to you that he's looking forward to testifying before the committee at the committee's convenience. He is very excited and enthusiastic about the prospects and possibilities of the Council, and I think that his appointment as Chairman shows that the administration is serious about this Council, and it will hopefully meet many, if not all, of the goals that have been set forward in the legislation.

Mr. BROWN. Dr. Moore, if I may interrupt you just briefly, I want to thank you for those comments, for Mr. Hodel's remarks. We have high regard for him and know that he can do a good job here if he is not subject to obstacles which are impossible to overcome, and we do look forward to hearing from him and will plan on calling him before the subcommittee probably early in the next year.

You may continue.

Dr. MOORE. I would like to also at this point read his statement of yesterday on his appointment to the chair of the National Critical Materials Council. He said,

> Strategic and critical materials play a fundamental role in the development of a vigorous economy and a strong national defense. Economic strength is vital to our ability to keep the peace of the world and, if necessary, defend militarily against foreign attacks upon the liberty of the United States or our allies. We could not be content with a situation where we lacked the availability of materials critical to ensuring our peace and freedom. We must be sensitive to those policies and programs which could have adverse consequences to the critical and strategic capability of the Nation which impact the health of our domestic minerals industry and which limit our ability to stay abreast of advances in technology. I welcome the opportunity to serve the President as Chairman of the National Critical Materials Council with William Martin, deputy secretary of energy, who has been named by the President to fill the second vacancy, and Tom Moore of the Council of Economic Advisers, who remains as a third member. I look forward to working aggressively with them to develop options which will facilitate our domestic industries' ability to make an effective contribution to the Nation's economic health and strategic well-being.

So I think the prospects are looking definitely up for the Council at this point.

Mr. BROWN. We hope so.

Dr. MOORE. Mr. Chairman, members of the subcommittee, and ladies and gentlemen, I appreciate the opportunity to appear before this distinguished panel this morning to discuss with you the vitally important subject of materials, their contribution to the Nation's economy and security, and the role of the National Critical Materials Council.

I would like, first of all, to acknowledge all the efforts of this subcommittee to create the council, and I would also like to thank your key staff members, Paul Maxwell, Tom Weimer, and Harriet Smith, for the support they have offered our staff. Dr. Maxwell has been particularly helpful in providing advice and guidance and making introductions throughout the materials community.

You on this panel are already aware of the importance of materials to America's and the industrialized free world's security and strength, but I still think it is worthwhile to dwell for a moment on this fact. Reliable, economically produced materials are essential to all of our Nation's critical industries—aerospace, automotive, electronics, communications, machine and farm tools, chemicals, and food processing, to name just a few.

Continued improvements in material are essential to advances in critical industries, such as faster and smaller computers; faster and more maneuverable aircraft; tougher, more versatile sensing devices; more durable machine tools and agricultural equipment; stronger, more heat resistant, and more corrosion resistant turbines, refractories and housings in the energy and electric power industries; lighter, more fuel-efficient automobiles.

Advances in material are changing many consumer industries as well. Food packaging, for example, benefits from improved poly-

mers, as do textiles and clothing. Housewares are improving with better ceramics. Sporting equipment fabrication is on the cutting edge of new composites, and construction is seeing major changes in metals, polymers, and ceramics.

Many of America's most dynamic corporations are focusing on material issues, whether we look at material processors, like Standard Oil, Coors Ceramics, Alcoa, Du Pont, and Corning, or materials users in aerospace, Detroit, or the computer industry. Likewise, there is an explosion of small entrepreneurial companies committed to the production or exploitation of newer materials.

The materials revolution is just as important to America as the revolution in electronics and computers yet is nowhere nearly as widely appreciated. This, I believe, is in large part because materials tend to be taken for granted by the ultimate users; they are somehow invisible.

How many airline travelers, for example, think for a moment about the alloys making up the aircraft whose reliability they implicitly trust? How many office computer users think for a moment about the materials improvement going into the microchips that are the brains of their equipment? One of the roles of the National Critical Materials Council, I believe, is to help increase public awareness of the importance of materials to industrial progress.

The Council, as you know, has a very broad mandate ranging from problems confronting mining, such as environmental controls and land access, through the public policy issues facing mineral processing and metal fabrication, to technical questions of how best to deploy advanced materials research and development funds. It is essential that in sorting out what should be of priority concern to the Council we bear in mind the need for an appropriate balance between established, large volume materials and new, more experimental materials.

In order to help deepen our appreciation of the range of public policy issues facing the materials industry, we have made a number of field trips. At Du Pont, for example, we saw state-of-the-art work on advanced carbon fibers. At Rutgers Ceramics Center, we saw an exemplary program of Government-industry-university cooperation in advanced ceramic work, and fascinating experiments on new uses of optical fibers and advanced production techniques for such fibers.

At operations of two of the Nation's major copper producers, Newmont Mining and Phelps Dodge, we saw a strong commitment to innovation: in Phelps Dodge's Hidalgo flash furnace and in Newmont Mining's solvent extraction-electrowinning plant, in situ leaching experiments, and block caving mining processes, all at its San Manuel complex; and at Nucor Steel we saw an impressively managed and impressively profitable mini-mill which had just successfully tested a new continuous feed melting operation, unique in the world, that is expected to cut costs $15 per ton.

In addition, we have met with key officials at the American Iron and Steel Institute to discuss the full range of steel issues which are of particular concern to me because, in my capacity as a member of the President's Council of Economic Advisers, I participate in the administration's Steel Working Group.

I would like to take this opportunity to make a general observation about our Nation's metal industries. Despite all the gloom and doom we hear from various quarters about America's metal industries, the impressions I gained in the field were of operations with real vitality.

As I indicated, all the facilities we visited were heavily involved in innovation in one way or another, and all were fully aware of the need to improve productivity and were committed to that goal. We saw a labor force that was hard working, ingenious and dedicated, and management that saw the need to change with the times. This is a far cry from the caricature of steel and copper one so frequently encounters.

To be sure, these industries face problems, not the least of which are stringent environmental controls. Without going into detail, because I have not had the chance to carefully study the financial details, it is my clear impression that the Government needs to take a more balanced view of the capital and operating costs imposed by current environmental regulations versus the environmental benefits produced.

I would now like to turn to consideration of three major council projects called for by the Critical Materials Act of 1984—a critical materials inventory, involvement in the materials R&D budget process, and an advanced materials R&D program plan.

We have chosen to focus the critical materials inventory on a select group of critical metals—namely, copper, aluminum, cobalt, chromium, ferro-silicon, titanium, and germanium. This is not to imply that many advanced materials, such as carbon-carbon composites and gallium-arsenide, are not critical, as they obviously are.

Our choice of metals is meant to select materials that are critical in their own right, but that also represents larger categories. Copper and aluminum represent high volume metals; cobalt, chromium, and ferro-silicon, representing steel alloying materials; titanium and germanium, representing newer metals with high growth potential.

The study will include a separate article, running about 2,000 words, on each of these newer metals. We will review trends and conditions of production and consumption to see if there are likely to be any significant problems in the foreseeable future. We are moving along in this process, having gone through various drafts of each piece, and will have a completed document as soon as possible.

Turning now to the materials R&D budget evaluation process, I am pleased to report that we are making progress on our involvement in the materials R&D budget process and have received good cooperation from the involved agencies. This, as I am sure you can appreciate, is no minor accomplishment, since materials R&D requests are not normally separated from general R&D in all agency budgets.

We have established working relationships with the various OMB budget examiners and will be reviewing fiscal year 1988 materials R&D requests as they are submitted. Inevitably, the first budget cycle mainly will be an experiment for us, and by the next budget cycle we should be much more fully integrated into the budget review process.

Finally, I would like to discuss our efforts to date on the Advanced Materials R&D Program Plan. The program plan, as I am sure you are aware, is a most challenging assignment.

As we reviewed the situation, it became evident that there were several possible approaches, and since you, Mr. Chairman, expressed special interest in this topic, I would like to review these approaches and indicate what we see as the advantages and limitation of each.

By material group—that is, metals, polymers, ceramics, semiconductors, composites. This approach makes a great deal of sense. It uses scientifically recognized categories, and much of the industry and Government work is organized this way. The major limitation is that it does not focus on the final uses of the materials. Work at materials-oriented agencies, such as the Bureau of Mines, is particularly well suited to this approach.

By mission. The advantage is fairly self-evident. This approach lets us see the purpose of various advanced material R&D projects. The biggest limitation is that there are a wide variety of Federal missions involving materials and that they would not be easy to group meaningfully. Work at agencies with relatively precise missions, such as NASA, is particularly suited to this analytical approach.

By Federal agency involved—that is, Department of Energy, Department of Defense, National Aeronautics and Space Administration, National Science Foundation, Department of Interior, Department of Commerce. These are the agencies with major interests in materials R&D. This is the obvious approach for initial collection and organization of data; in fact, it is an indispensable approach. Its limitation is that it does not afford a Governmentwide, cross-cutting perspective.

By properties, such as strength, density, or special magnetic, electrical, or optical properties. This approach could be particularly useful in special cases—for example, looking at cross-agency efforts to develop heat- and corrosion-resistant materials suitable to high performance turbines. However, in general, this approach would be difficult to implement, as there would be serious problems of definition and classification. Furthermore, in many cases, looking at desirable combinations of properties would be little different from taking a mission-oriented approach.

By industry affected—for example, aerospace, automotive, telecommunications. This market-oriented approach would have the advantage of putting advanced materials in the context of America's most critical industries. A serious disadvantage is that needed data would be very difficult to collect since the industries involved usually view much of it as proprietary and, in any case, would consider requests for such information burdensome. Moreover, many materials are used in a great number of industries, and there is no good way to predict all the industries which might find a use for some materials.

By level of research—that is, basic, applied, or systems-specific, or, in budget terms, 6.1, 6.2, or 6.3 research. This approach yields a great deal of information indirectly about a research project, such as what is the expected pay-back timeframe, how wide-ranging are its implications, and whether it is generally university, industry, or

Government oriented. The major limitation is that the subject matter is not the focus of attention. Work at agencies doing clearly defined levels of research, such as the National Science Foundation, lends itself particularly well to this approach.

All these approaches have advantages and limitations. We are currently reviewing with the agencies which of these or which combination might be the best approach. In any case, our plan is intended to be a dynamic document that will be available for review and comment by the public. As we proceed, revised plans will inevitably be more fully integrated, better reflect a Governmentwide perspective, and embody more thoroughly articulated national objectives.

In addition to these three projects just described—the critical materials inventory, the materials R&D budget process, and the advanced materials R&D program plan—the Council is looking at specific materials issues.

We watch closely the development of mine waste regulation issue, noting with satisfaction the Environmental Protection Agency's decision to regulate mine waste under subsection D rather than subsection C of RECRA.

We are investigating the issue of intellectual property rights, with the particular intention of insuring that the process of technological innovation is not frustrated by existing law.

We are reviewing the effects of Federal regulation on the introduction of new materials—for example, use in aircraft construction—and we are looking at the relationship between Government research efforts and those of academia and industry. The NSF-funded research center at Rutgers, for example, is an excellent example of how Government-university-industry cooperation can work. The NSF Center model might be appropriate elsewhere.

I would like to close by thanking the committee for its attention and continued interest in the vital subject of materials. I would be happy to take questions.

[The prepared statement of Dr. Moore follows:]

TESTIMONY OF THOMAS GALE MOORE

ACTING CHAIRMAN, NATIONAL CRITICAL MATERIALS COUNCIL
EXECUTIVE OFFICE OF THE PRESIDENT
BEFORE THE
SUBCOMMITTEE ON TRANSPORTATION, AVIATION AND MATERIALS
COMMITTEE ON SCIENCE AND TECHNOLOGY
UNITED STATES HOUSE OF REPRESENTATIVES
SEPTEMBER 17, 1986

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And continuing improvements in materials are essential to advances in critical industries, such as:

- faster and smaller computers
- faster and more maneuverable aircraft
- tougher, more versatile sensing devices
- more durable machine tools and agricultural equipment
- stronger, more heat-resistant and more corrosion-resistant turbines, refractories and housings in the energy and electric-power industries
- lighter, more fuel-efficient automobiles.

Advances in materials are changing many consumer industries, as well. Food packaging, for example, benefits from improved polymers, as do textiles and clothing. Housewares are improving with better ceramics. Sporting equipment fabrication is on the cutting edge of new composites. And construction is seeing major changes in metals, polymers, and ceramics.

Many of America's most dynamic corporations are focusing on materials issues, whether we look at materials-producers like Standard Oil, Coors Ceramics, Alcoa, Du Pont and Corning, or materials-users in aerospace, Detroit, or the computer industry. Likewise, there is an explosion of small entrepreneurial companies committed to the production or exploitation of newer materials.

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- At Du Pont, for example, we saw state-of-the-art work on advanced carbon fibers.

- At Rutgers Ceramics Center, we saw an exemplary program of government-industry-university cooperation in advanced ceramic work, and fascinating experiments on new uses of optical fibers and advanced production techniques for such fibers.
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I now would like to turn to consideration of three major Council projects called for by the Critical Materials Act of 1984:

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- involvement in the materials R&D budget process; and
- an advanced materials R&D program plan.

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cobalt, chromium, ferro-silicon, titanium, and germanium. This is not to imply that many advanced materials, such as carbon-carbon composits and gallium-arsenide, are not critical, as they obviously are.

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vanced materials R&D projects. The biggest limitation is that there are a wide variety of federal missions involving materials, and they would not be easy to group meaningfully. Work at agencies with relatively precise missions, such as NASA, is particularly suited to this analytic approach.

- By federal agency involved--that is, Department of Energy, Department of Defense, National Aeroanutical and Space Administration, National Science Foundation, Department of Interior (Bureau of Mines, Geological Survey), and Department of Commerce (Bureau of Standards). These are the agencies with major interest in materials R&D. This is the obvious approach for initial collection and organization of data; in fact, it is an indispensable approach. Its limitation is that it does not afford a government-wide, cross-cutting perspective.
- By properties--such as strength, density, or special magnetic electrical, or optical properties. This approach could be particularly useful in special cases, for example, looking at cross-agency efforts to develop heat and corrosion-resistant materials suitable to high performance turbines. However, in general, this approach would be difficult to implement, as there would be serious problems of defini-

tion and classification. Furthermore, in many cases, looking at desirable combinations of properties would be little different from taking a mission-oriented approach.

- By industry affected--for example, aerospace, automotive, telecommunications. This market-oriented approach would have the advantage of putting advanced materials in the context of America's most critical industries. A serious disadvantage is that needed data would be very difficult to collect, since the industries involved usually view much of it as proprietary and, in any case, would consider requests for such information burdensome. Moreover, many materials are used in a great number of industries and there is no good way to predict all the industries which might find a use for some materials.
- By level of research--that is, basic, applied or systems-specific, or, in budget terms, 6.1, 6.2, or 6.3 research. This approach yields a great deal of information indirectly about a research project, such as what is the expected "pay-back" time frame, how wide-ranging are its implications, and whether it is generally university, industry, or government oriented. The major limitation is that the subject matter is not the focus of attention. Work at agencies doing clearly defined levels of research, such as the National Science Foundation, lends itself particularly well to this approach.

All these approaches have advantages and limitations. We are currently reviewing with the agencies which of these or which combinations might be the best approach.

In any case, our plan is intended to be a dynamic document that will be available for review and comment by the public. As we proceed, revised plans will inevitably be more fully integrated, better reflect a government-wide perspective, and embody more thoroughly articulated national objectives.

In addition to the three projects just described--the critical materials inventory, the materials R&D budget process, and the advanced materials R&D Program Plan--the Council is looking at specific materials issues:

- We watch closely the development of the mine waste regulation issue, noting with satisfaction the Environmental Protection Administrator's decision to regulate mine waste under Subsection D, rather than Subsection C, or RECRA.
- We are investigating the issue of intellectual property rights, with the particular intention of insuring that the process of technological innovation is not frustrated by existing law.
- We are reviewing the effect of federal regulation on the introduction of new materials--for example, use in aircraft construction.

- And, we are looking at the relationship between government research efforts and those of academia and industry. The NSF-funded research center at Rutgers, for example, is an excellent example of how government-university-industry cooperation can work. The NSF Center model might be appropriate elsewhere.

I would like to close by thanking the committee for its attention and continued interest in the vital subject of materials.

I would be happy to take questions ...

Mr. BROWN. Thank you very much, Dr. Moore.

Dr. Moore, your statement is an excellent statement of your agenda for your future activities. You're moving in the direction, I think, that the legislation contemplated. Our problem has been that it appeared that actual concrete results were rather sparse, and of course the committee and, I think, the Congress expects a little more aggressive pursuit of your basic mission, which is that of assisting in the development of strategic policy options which can help us to achieve greater effectiveness in this area.

As you know, the legislation was structured in an effort to make it as compatible as possible with the administration's desires. There's no effort to establish a fight between the Congress and the administration. The President has full control, and the whole operation is intended to help him do a more effective job in an important area of national policy vital to the industrial competitiveness of the United States in world markets.

Having said that, there is, however, an expectation that the purposes of the law would be fulfilled in a reasonable way, and I think the Congress has every right to expect that. I think you would—I hope you would agree with that statement, and our problem has been, as we pointed out in our opening statements, a feeling that we were not moving ahead very vigorously.

Having said that, can you give us some idea of what we might expect in terms of the pace of accomplishment, given that we now have a new and highly capable Chairman, Secretary Hodel, as well as a full complement of Council members, all of whom we have great respect for, including yourself. Do you think that this will have a salutory impact on the pace in which you will be able to move in accomplishing the things that you have set forth here?

Dr. MOORE. I cannot, of course, speak for Mr. Hodel, but I am very optimistic. In fact, I know from his interest in this whole area that he plans to move ahead very vigorously.

We have been, as you know and you have reflected—we have been short-handed, we have been missing the other two members for some time, and we have been feeling our way in this area, trying to learn about the area. So I would hope that the Congress and the committee would understand that we have been trying to move ahead as rapidly as possible, but it is a new area, and we have been very limited in the Council being missing two of its members.

But Secretary Hodel is, as you know, a dynamic man, and he has a very strong interest in this area. So I think I am not going out very far on a limb by promising you that there will be much more aggressive action in this area in the future than you have seen up to now. But even under the best of circumstances, it takes a while for a new agency, a new committee, to get its bearings and see where it's going, and these are, in fact, not simple issues.

Mr. BROWN. No, we very much appreciate that, and we understand the limitations on the Council and on the staff. You are operating with, shall we say, relatively limited manpower resources, of high quality but ultimately limited, and we might inquire if you don't perhaps think you might seek a little more aggressively to augment the staff resources that you have in light of the fact that

you haven't come anywhere close to the level which the Congress has authorized.

Dr. MOORE. I think if we have the resources we undoubtedly, or very likely, will augment the staff, as Secretary Hodel sees the need for.

I might point out, Mr. Chairman, that I understand that the House Appropriations Subcommittee cut our budget to $100,000, which means that we will not—excuse me, it was the Senate—which would make it very difficult for us to continue the existing staff.

Mr. BROWN. You have a good point there.

Dr. MOORE. Mr. Chairman, let me just add that the Council can and has drawn on much of the resources throughout the Federal Government, such as Dr. Morgan, who is with us, and Secretary Hodel will, of course, have the whole Department of the Interior at his beck and call.

Mr. BROWN. Yes.

We note that the sum of $500,000 was appropriated to the council for this fiscal year. One of the reasons that the Senate Appropriations Committee may have acted in the fashion you describe may be due to the fact that you didn't spend very much of that $500,000. I don't know at this point, and I'd like to ask you, if you can provide us with the information, as to how much has been spent by the Council in this fiscal year and how that money was spent, and provide us with such detail as might be helpful to us in assisting you in getting a somewhat larger amount of resources.

Dr. MOORE. Unless Brien Benson has the numbers, I think we'd have to submit that to you in writing. I cannot give you the numbers right off the top of my head.

Mr. BROWN. Well, can I just ask you to give me a rough number, like, is it more or less than $100,000?

Dr. MOORE. I think we are spending at the rate of over $100,000, maybe $150,000, at this point.

Mr. BROWN. You see, when the Congress is as concerned about expenditures as it is, they have an attitude of sort of freezing you at the level that you're at, and if you're not using the $500,000 appropriated, they're likely to say, "Well, let's just give you what you're using."

Dr. MOORE. We're not asking for $500,000 for next year.

Mr. BROWN. That's part of the problem, too.

Dr. MOORE. Because, actually, we don't think that we need that level of resources at this point. But $100,000 is inadequate to continue the existing staff, and therefore we are asking for more, and we are spending about $150,000.

Mr. BROWN. We will ask you to provide that as definitively as you can, with some indication—and it shouldn't be too difficult—to detail what $150,000 went for, and we'll make an honest effort to make sure that you get a more reasonable amount of money than you have indicated here.

[The information follows:]

NATIONAL CRITICAL MATERIALS COUNCIL
EXECUTIVE OFFICE OF THE PRESIDENT
2401 E Street, N.W. Room W-725
Mail Station 1100
Washington, D.C. 20241
(202) 634-1993

25 September 1986

Honorable George E. Brown, Jr.
Chairman, Subcommittee on Transportation,
Aviation and Materials
Committee on Science and Technology
U.S. House of Representatives
Washington, D.C. 20515

Dear Mr. Chairman:

Per your request at the oversight hearing on September 17, 1986, I am listing below the Council's expenses for the first 11½ months of fiscal year 1986:

Personnel costs	$ 58,200
Travel	5,700
Rent and utilities	13,200
Services and consultants	32,800
Supplies	2,800
Word processing equipment	12,300
TOTAL	$125,000

These expenses were incurred almost exclusively during this calendar year.

Thank you for your interest in the Council's activities.

Sincerely,

Brien G. Benson

Brien G. Benson
Executive Director

Mr. BROWN. Are you anticipating during the next fiscal year any significant changes in the kind of activities the Council has been conducting? For example, with Secretary Hodel on the Council, would there be a greater interest in the minerals and mining area, which is of great concern to many members of this subcommittee, or other changes in focus that might be useful for us to know about?

Dr. MOORE. Mr. Chairman, I would not anticipate any great change in focus. Secretary Hodel, as you indicate, has a very strong interest in minerals and mining, but he has taken on this role as chairman of the National Critical Materials Council to look at all materials issues, including the advanced materials, and I'm sure he plans—I feel confident in saying he plans to continue work and concern with those issues as well as the mining and more basic metals.

Mr. BROWN. We will probably want to explore that more fully with Secretary Hodel at the hearings that I indicated we might want to conduct in the spring of next year with regard to this matter.

Can you give me any indication of who or how you intend to carry out the critical materials inventory? You have described a process that involved some preparation of reports in this area. It could be a fairly substantial task, and we're interested in knowing how you propose to carry this out more extensively.

Dr. MOORE. Mr. Chairman, what we are doing is drawing on other agencies—in particular, in this case, the Bureau of Mines—to help us prepare the materials inventory. In my prepared testimony, I listed the materials we were initially going to review in our inventory, and for that purpose the Bureau of Mines is helping, doing the basic drafting of our report, which we are going over for the final document, and so what we would intend to do in this whole inventories area is draw on other Government agencies.

It is not my view of the Council's role that it should establish a large bureaucracy itself. There are lots of Government agencies which we can draw on to help us prepare the inventory, and that's going to be our game plan in the future and is what we are doing now.

Mr. BROWN. We have no fault with that process as long as we know you've got a game plan, Dr. Moore.

Let me ask, you are focusing on the utilization of assistance from outside the Council itself, and perhaps Mr. Benson could respond, if he wishes, or both of you. I'd like to know how you are proceeding to involve the private sector here. As you know, we have, and what we believed was, being in accordance with the administration's philosophy, put a great deal of emphasis of a cooperative approach to this using resources in consultation with the private sector, including the academic sector. We'd like to know what efforts or plans, if any, have been made to move in this direction.

Dr. MOORE. Before I turn it over to Mr. Benson, let me just say that we have held a hearing to hear the private sector, we have met with many individuals in the private sector, we have made a number of field trips, we've talked to people from the American Iron and Steel Institute, we've been up to Rutgers, talked to the scientists up there, to Du Pont, to their researchers, we've visited

copper facilities, steel facilities. So we've been trying to reach out to the private sector.

Brien, what else would you like to add?

Mr. BENSON. I would just like to add to that such organizations as the Federation of Materials Societies, which I think does an outstanding job of representing a wide variety of materials interests, both industrial and academic. You will, of course, be hearing from them later this morning.

We have had—you will be hearing from representatives of USACA, in particular, Standard Oil's operations in this area. We have had conversations with them, are sensitive to their concerns. The National Materials Advisory Board within the National Academy of Sciences, we are working with. In fact, this evening I will be going to an NMAB dinner.

So we are continuing to expand our contacts both in the academic and industrial communities that are concerned with materials issues, and, in addition, I would point out that, as Dr. Moore indicated in the testimony, as the program plan unfolds, it will, of course, be available for public review, and we will be looking forward to input from both the world of industry and the academy.

Mr. BROWN. May I say that we applaud your efforts to expand your contacts and to gain greater familiarity with the problems of the various sectors. That's obviously the first step in developing an interactive policy review process, but it's only the first step, and we're looking forward to seeing the second step, maybe even a third step here.

Please understand that our role is to put the heat on you, and we're trying to do that. There's no effort to——

Dr. MOORE. I feel warm.

Mr. BROWN. This is not done with any animosity or any feeling that you're not acting in good faith, but we're going to keep the heat on you, and we expect to see more than establishing contacts or familiarizing yourself with the conditions of industry and so forth. This was not the reason the legislation was enacted. We don't want to create a warm, friendly feeling out there and have a lot of friends, we want to establish coherent national policies that will achieve a national goal. That's the purpose of the legislation.

Mr. Lewis.

Mr. LEWIS. Thank you, Mr. Chairman.

Dr. Moore, since you have been appointed to the Materials Council, what have you learned about the problems of this country in minerals and the materials area, just generally?

Dr. MOORE. I've learned a great deal, I think, about advanced materials in particular which I was unaware of, that there are remarkable things being done in advanced material, and we are in a technological race with other countries, with the Japanese in particular in ceramics, and that it is important for us to continue to do research and advance in this area. These are critical areas to our future well-being. They are going to be the basis of major industries in the future and in the aerospace area and just a whole wide variety of areas. These materials are going to play a large role.

It was remarkable to me what is being done, and it's also of concern that in fact we—that in some ways the Japanese are doing

more in the ceramics area at least than we are; that's of some concern.

I've also learned a good bit in the area of minerals—the basic minerals area, particularly copper—what is going on in the environmental regulations and how that is impacting the copper industry, and I think that more consideration has to be made there, weighing some costs and benefits. It's not clear to me that they have always been weighed.

Again, I need to learn more about the costs involved here and the benefits, but from what I've learned to date, there are some critical and important issues there that must be addressed, and then there is a lack—there is difficulty in accessing land—Federal land, which may have significant mineral deposits, and because of a variety of laws it's difficult for these to be accessed and explored and mined, and this is another important area which I think is vitally necessary for us to move forward in.

Mr. LEWIS. Dr. Moore, you have a very impressive background. From your background and experience, do you really believe that the Council can help, or is this just another stonewalling bureaucracy?

Mr. MOORE. I believe the Council can help. I don't believe the Council can create—will create miracles, but I think the Council can, in fact, help. It can point things out, as we review R&D budgets, for example. In fact, we are already involved in doing that and in talking to some of the agencies about, "Well, maybe what you're doing is duplicating what some other agency is doing over here, and this may not be the best expenditure of your funds." So I think we can do work there.

We can focus a lot of attention on materials issues which haven't been focused before, and, as I just said, I, myself, have become much more aware of materials and materials issues than I ever was before I took this job when I just essentially took materials for granted, as something that was there and somehow appeared there.

Mr. LEWIS. Dr. Moore, as Acting Chairman of the Council and with the act authorizing up to 12 positions, as to one of the questions that the chairman asked, why hasn't the Council employed personnel with the appropriate expertise in these areas?

Dr. MOORE. Basically because we can draw for nothing on other Government agencies for the expertise, and I don't think that a large bureaucracy is necessary or desirable. I might say that, as you know, I'm a member of the President's Council of Economic Advisers, and we have a very small staff there and, I think, do a very good job with a very small staff.

So I don't think the size of the staff should be a criteria for whether the Council is doing its job. We can, in this case, draw on expertise elsewhere in the Government if we need to know more about a particular mineral or particular research. There are experts out there.

Even with that size, the 12 people you refer to, we could not cover all the issues, so it's much better for us to stay small and draw on other Government agencies for our expertise.

Mr. LEWIS. But isn't it a fact, if you're drawing expertise from other agencies, that their role for you is secondary and that their primary role is to the agency that they answer to, and wouldn't

you be further ahead by having your own pool of expertise so that you could get this thing moving and perform what the act requests rather than be a second cousin or like a volunteer, receiving volunteers in a political campaign that are never around?

Dr. MOORE. We're all part of the same administration.

Mr. LEWIS. I understand that, but I also understand that if you want to follow a particular project or program within your department in meeting the act that we've created, it would seem to me that you would want your own expertise to follow that and meet the milestones within a reasonable timeframe. That's the thing I'm driving at.

Dr. MOORE. Certainly if we find that we are not getting the cooperation and the expertise that we need from other agencies, then we will want to move out and hire our own. Up to now, we've been getting full cooperation and expertise from other agencies. That doesn't mean, and I would not want to preclude us hiring additional staff. This will be up to Secretary Hodel and the whole Council when we meet, and we will discuss this. As we need expertise, and if we need some full-time expertise in some areas, we may very much desire to hire some additional staff. I would not want to preclude that. But up to now, we have been feeling our way, we've been learning from other agencies, and it's largely been a learning process, and for that purpose we do not need a large staff.

Mr. LEWIS. Well, I guess I just have a problem with that, Dr. Moore. It seems that the act has been effective for 2 years and you're still feeling your way. It would seem to me that if we're going to meet, as the chairman pointed out, the requirements of the act, then you'd want your own expertise.

Is this particular act and the National Materials Council really important to the future of this country?

Dr. MOORE. I think it's an important agency. We have important tasks to perform. While the act is 2 years old, for better or worse, as you know, I was not appointed until last November, and I came into this job as a complete neophyte in the area of materials. So I, for one, have been spending the time learning about the issues involved, and we did not see the need at this point to have a large staff. Secretary Hodel may decide that we need to have more expertise, and we'll move forward. But I'm very optimistic that we will move forward aggressively in the future now we are back up to strength, and we have a dynamic chairman with a strong interest in this area.

So I would hope that you do not write off the Council at this point. We do plan to move ahead.

Mr. LEWIS. No, I won't write the Council off, Dr. Moore, because I did support the act and I believe in it. I'm just astonished. Here's a governmental group that has open positions and they're not going helter-skelter to fill them; it's just astonishing to me. But I certainly would hope that the importance of the Council is not overlooked in the direction that Congress sees it.

From what I hear from other areas of the industry, there's a great concern about our critical metals and materials, and it just seems that—I have a problem trying to see that sense of urgency within the Council itself. Maybe I'm overlooking this or I don't see something that really is there, and, if so, I apologize for that, but I

think we have a real critical metal and materials policy problem in this country.

Thank you, Mr. Chairman.

Mr. BROWN. How large a staff do you have at the present time?

Dr. MOORE. At the present time?

Mr. BROWN. Yes.

Dr. MOORE. Well, we have Brien Benson, and he has a secretary, and we have some consultants.

Mr. BROWN. You wouldn't describe that as a large bureaucracy, would you?

Dr. MOORE. I do not.

Mr. BROWN. Even with two or three more people, it wouldn't be a very large bureaucracy.

Dr. MOORE. Well, a few people here and a few people there, and pretty soon it adds up to real numbers.

Mr. BROWN. You described your process of becoming involved in the budgetary process, your getting acquainted with the budget examiners and so forth. The act contemplates that this involvement with the budget process be a dynamic process involving the development of a framework within which policy decisions can be made—for example, the development of an advanced materials R&D program plan.

Only within the existence of such a framework can you make decisions with regard to the desirability of the various budget requests that come in and begin the process of integrating these into a coherent program. Do you have such a program plan in process of development?

Dr. MOORE. I described in my testimony that we were developing a program plan to look at various materials issues on various bases, but we are moving ahead even now on budgetary issues. As I indicated again in my testimony, we have been meeting with the budget examiners, we've been talking to some of the agencies, and consulting with them on their budget and their R&D expenditures. So we are moving ahead, and we are moving ahead with a program plan.

Mr. BROWN. You devoted a considerable part of your statement to discussing the various options, I guess you might say, with regard to how you could focus on such a plan, and I think that your description indicates your growing awareness of the many-faceted aspects of this. It's not all that reassuring as to what you actually have done.

Your statement is, "We are currently reviewing with the agencies which of these or which combinations might be the best approach." You could spend the next year discussing which of these might be the best approach. We're looking for the development of a program plan under which fundamental budgetary decisions can be integrated in the interests of a coherent national program. That's the question I'm asking.

Dr. MOORE. Well, we will not spend the next year reviewing these options with the agencies, we are planning to move ahead more rapidly than that, but now that—I think that any decision on exactly how we move ahead should wait on Secretary Hodel and Bill Martin and myself together reviewing this, and we've not had

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a chance to do that. So, as I said in the testimony, we're reviewing with the agencies.

We'll now be making some decisions within the Council on how to proceed with this, and I feel confident we can assure you that we will be moving ahead and developing such a program plan. So this is just the options we've been reviewing. I think it is a very complex subject, and one should not want to jump quickly into it without reviewing carefully what you're doing.

Mr. BROWN. We're not going to accuse you of jumping quickly, Dr. Moore.

What I'm afraid of is that when Mr. Hodel comes on board, he's going to want to review all of these complex options, and he may take a year also, as you have, and next year, when we have our hearings, he's going to report the great difficulty in analyzing all these options and explain why he doesn't have a program plan yet. We don't like to have that. We're trying to convince you that a little more aggressive role is required, and that includes providing the necessary staff to develop this. It is a complex process, we don't underestimate it, but that's the heart of what we're trying to achieve here.

Well, I don't want you to feel that you're being picked on. This is just a friendly exchange of views, and we appreciate very much—oh, I'm sorry; Mr. Packard, whom I overlooked.

Mr. Packard.

Mr. PACKARD. I wouldn't want you to overlook me, Mr. Chairman.

In your testimony, Dr. Moore, very little was stated concerning strategic metals involved in the military. I think you mentioned the Defense Department in a place or two, but little in the military. Is the intent of your council to review that aspect of critical and strategic materials in terms of its impacts upon our military preparedness, et cetera?

Dr. MOORE. Well, we do have a broad mandate that would include national security considerations, and we do plan to take that into consideration and work on that. But there are other agencies in the Government—the Defense Department, National Security Council—which are much more directly concerned with those kinds of issues, and we will work with them. But clearly much of the direction there will have to come from them.

We hope to be able to focus better our R&D budget on advanced materials, and this will, in fact, be helpful for defense and national security purposes as well as for economic advancement.

Mr. PACKARD. In your studies thus far, have you been able to evaluate how much of our resources are of domestic origin and how much are of foreign origin, and have you been able to evaluate what impacts that has upon our own stability here in this country, not militarily but I mean generally in all aspects of industry?

Dr. MOORE. As you are well aware, some materials we import virtually all that we use and some we produce almost entirely ourselves. It varies greatly by material, and I'm aware of that. This has been looked at within the administration in terms of national security considerations, and we are fully aware of that at the Council. We are concerned to make sure that we do have adequate supplies in case of a national emergency of critical materials, and we

are concerned that we will have them available in such a situation. So that is something that is being considered and looked at by us.

Mr. PACKARD. Is one of your roles to advise the administration in regard to critical materials on foreign policy or on at least the effects of foreign policy decisions? A point that comes to mind would be South Africa and the problems we struggle with there in making both congressional decisions as well as administration decisions on our approach to dealing with South Africa, and obviously there are critical and strategic materials involved. Is part of your role to advise the administration on the effects of those decisions relative to critical materials?

Dr. MOORE. I would say the Council's role is advising the President and the administration on all issues that impact on critical materials, and we clearly will not be the ultimate decisionmaking body here, but I think that it is part of our role to indicate if, in fact, we think that some sort of policy decision, foreign or domestic, is going to adversely impact a critical material, it should be our role to bring that to the attention of the administration.

Mr. PACKARD. Are you adequately staffed and adequately functioning to where you could provide them with the necessary information that would give them direction on policy decisions relative to not just a country like South Africa but any other country?

Dr. MOORE. Well, we've reviewed the work that is—or I've reviewed the work that's been done in this area, and I think that—and we have staff, Brien Benson and other people within the administration, and, as I said earlier, we do call upon other agencies for advice. So we can get a lot of expertise elsewhere and have been drawing on a lot of expertise elsewhere. So I think we are in a position to alert people if there is something—some major issue in this area.

Mr. PACKARD. Thank you, Dr. Moore, Mr. Chairman.

Mr. BROWN. Mr. Lewis had another question.

Mr. LEWIS. Thank you, Mr. Chairman.

Dr. Moore, I'd like to ask Mr. Benson a couple of questions, if I may.

Mr. Benson, who do you direct? You're the Executive Director of the Council. Who do you direct?

Mr. BENSON. As Dr. Moore has said several times, and I heartily agree with him, there is an awful lot of talent in the Federal Government both in the area of basic minerals, in the area of metallurgy, and in the area of advanced materials. One of the most impressive is Dr. Morgan, who is with us today, and there are many other people around.

So I have viewed my job in large measure as being a catalyst and a puller together, a teamster, if you will, to try to get—to try to mobilize and direct this talent to our tasks, and particularly the three that Dr. Moore outlined.

Mr. LEWIS. How can you direct a metallurgist at the Bureau of Mines to provide you with the necessary information you need to provide to Dr. Moore and other members of the Council? How can you direct him?

Mr. BENSON. Well, we have—my personal experience has been that people have been extremely cooperative and helpful.

Mr. LEWIS. But how can you direct them? You need to know about critical material A and precious metal B, and you contact a metallurgist at the Bureau of Mines. Just how do you direct him to give you the information and get a report back to you on that?

Mr. BENSON. Just exactly as you've outlined. I would get on the telephone.

Mr. LEWIS. You can tell him what to do, and he'll do it for you?

Mr. BENSON. I understand that during the course of the Civil War General Lee never once issued an order, per se, but gave his field marshals requests. So of course it's a matter of a request for support, and my experience has been that that support has been forthcoming.

Mr. LEWIS. How many direct employees do you direct at the Council?

Mr. BENSON. Well, as Dr. Moore indicated, I have an administrative assistant?

Mr. LEWIS. Pardon?

Mr. BENSON. I have an administrative assistant-secretary.

Mr. LEWIS. You have one administrative assistant. How many other people do you have?

Mr. BENSON. Well, that's——

Mr. LEWIS. That's it?

Mr. BENSON. Right.

Mr. LEWIS. Total. So we have two working for the Council right now.

Where are your offices?

Mr. BENSON. We're located in the Bureau of the Mines building.

Mr. LEWIS. Bureau of Mines building.

Mr. BENSON. Right.

Mr. LEWIS. And if you employed six people tomorrow, do you have desks and offices for them?

Mr. BENSON. Yes. I mean we would certainly be able to work——

Mr. LEWIS. Do you have space allocated for them right now? Where were you located——

Mr. BENSON. Yes. I mean we would be able to put together space; yes, sir.

Mr. LEWIS. Where are you located at the Bureau of Mines? I want to come and visit you.

Mr. BENSON. Well, I'd be delighted.

Mr. LEWIS. I just want to see what your operation is like over there, because I don't think you've got much of an operation, Mr. Benson.

Mr. BENSON. I would be delighted to have you, Congressman.

Mr. LEWIS. When you start giving me a history lesson, you sort of irritate me, and you're sort of bouncing around on the questions I ask you, so I'm going to come over and visit you directly, and I just want to see your operation. I want to see if you can be staffed for 14 people, if you have the equipment for them, and I also want a better indication of how you work directly with the Bureau of Mines and other agencies so that you can, as you say, through your request, direct them to do something, because I don't think you can direct anybody in those other agencies. I think your requests are going to go on back burners, and, just as I said earlier, that I don't think you have any control over them whatsoever, and I think you

have to have control for the Council over your own expertise and your own shop if you want to get the job done. Otherwise, you're fooling yourself and trying to fool us, too, and we don't fool very well, because we've been around the block a few times.

Thank you, Mr. Chairman.

Mr. BROWN. Thank you very much, Mr. Lewis.

Gentlemen, thank you for your appearance. I hope you'll be able to remain for the rest of the morning and listen to some of the other testimony, and we do appreciate your being here.

Dr. MOORE. Thank you.

Mr. BROWN. Our next witness is Dr. Peter Blair, who is the program manager for the Energy and Materials Program at OTA, and he is accompanied by Dr. Gregory Eyring, who is the project director the Energy and Materials Program.

I understand that Dr. Eyring will be testifying.

STATEMENT OF PETER D. BLAIR, PROGRAM MANAGER, ENERGY AND MATERIALS PROGRAM, OFFICE OF TECHNOLOGY ASSESSMENT, ACCOMPANIED BY GREGORY EYRING, PROJECT DIRECTOR, ENERGY AND MATERIALS PROGRAM

Dr. BLAIR. I'm Peter Blair.

Mr. BROWN. Are you going to introduce Dr. Eyring?

Dr. BLAIR. Yes. I'll give a few opening remarks and then turn the podium over to Dr. Eyring.

Mr. BROWN. Who really knows what he's talking about.

Dr. BLAIR. That's right.

Mr. Chairman, thank you very much for the opportunity to share with your subcommittee the findings of OTA's new technical memorandum that we're releasing today at this hearing entitled "New Structure Materials Technologies: Opportunities for the Use of Advanced Ceramics and Composites."

Mr. BROWN. This one?

Dr. BLAIR. Right.

Mr. BROWN. You should hold up a copy of it.

Dr. BLAIR. This study was requested by the House Science and Technology Committee and the Senate Commerce Committee to better define the many opportunities for high technology ceramics and polymer composites over the next 15 to 25 years and to determine the principal technical and related problems that need to be overcome if timely expansion of the commercial use of these materials is to take place.

This study is actually a sequel to an assessment we released last year entitled "Strategic Materials: Technologies to Reduce U.S. Import Vulnerability." The tech memo that we're releasing today, which is actually an interim report of our overall study on new materials, gives a series of research and development priorities. The second phase of the study, which is under way right now, deals much more with the issues of implementing the use of these new materials in the U.S. economy.

We're confident that the findings of the study to date will help contribute to a better understanding of the context within which your subcommittee maintains oversight of the implementation of the Critical Materials Act.

I would now like to turn the podium over to Dr. Eyring, our pillar of expertise at the agency, who is directing the assessment, and he will certainly be able to summarize our findings for you.

Mr. BROWN. Please proceed, Dr. Eyring.

Dr. EYRING. Mr. Chairman, I appreciate the opportunity to summarize for your subcommittee the results of OTA's technical memorandum on new structural materials which, as Peter said, is being released in conjunction with this hearing. The memorandum should be relevant to the activities of the National Critical Materials Council relating to advanced materials.

We find that new materials offer very significant opportunities in both military and commercial applications in the next 25 years and that the Federal role in realizing those opportunities is likely to continue to be very important.

Advanced materials are often ranked with information technology and biotechnology as being the three most promising high technology industries of the future. Advances in materials science are of fundamental importance because they enable other technologies to go forward. For example, progress in micro-electronics depends on the availability of high purity semiconductor materials. Thus, materials provide multiplying benefits to the economy which far exceed the value of the materials themselves.

Structural materials may be classified as ceramics, polymers, metals, or hybrid materials derived from these called composites, as I have indicated in figure one at the back of my testimony. The properties of composites can be tailored to fit the specific requirements of a particular application, and, incidentally, I have brought a number of samples of these materials with me today for you to look at, if you wish. I'd be glad to pass those around.

Mr. BROWN. Please do.

Dr. EYRING. The past 25 years have witnessed remarkable developments in structural materials technologies. New non-metallic materials, such as ceramics and polymer matrix composites, are starting to replace metals in a wide variety of applications ranging from cutting tools to tennis racquets. The new materials represent both an opportunity and a challenge to U.S. manufacturing industries. In an era of concern about the long-term economic viability of the manufacturing sector, they open a promising avenue to renewed international competitiveness, new industries, and employment opportunities. However, these opportunities cannot be taken for granted. All of the industrialized countries are actively competing for the large commercial and military markets at stake.

Although the United States has a technological lead in the development of some materials, particularly those used in military applications, it often lags in developing commercial products. By comparison, Japan in particular has aggressive government-industry programs to commercialize its evolving materials technologies.

Ceramics can be defined to include all solids which are neither organic nor metallic. Compared with metals, ceramics generally have higher hardness, better high-temperature strength, and higher resistance to corrosion. However, they are also more brittle than metals, and this causes them to be less reliable than metals.

Current markets for structural ceramics are small. The present U.S. market size has been estimated to be about $300 million pri-

marily in heat and wear-resistance applications. However, projections to the year 2000 anticipate a rapid growth to between $1 billion and $5 billion for structural ceramics spread among many new applications.

Ceramics such as aluminum oxide, silicon nitride, and silicon carbide are currently in production for wear parts, cutting tools, bearings, and coatings. The market share of ceramics is generally less than 5 percent, but substantial growth is expected. R&D funding for these applications is being provided by industry and is driven by competition in a known market.

Ceramics are also in limited production in Japan in discrete engine components, such as turbochargers, glow plugs, and precombustion chambers, and I've brought with me today a silicon nitrite precombustion chamber courtesy of the Japanese company, Kyocera. Current military applications in the United States include ray domes for missiles, armor, infrared windows, and heat sources.

In the next 10 to 15 years, production of advanced ceramics will occur in new bearings, medical devices, various construction applications, heat exchangers, electro-chemical devices, and a variety of military applications. Very large markets are at stake, and especially promising are bioceramics that will be used in dental and orthopedic implants in the body. Several sources that we interviewed felt that medical applications of structural ceramics could provide the largest single dollar market by the year 2000. In many cases, Government funding will be required to solve the remaining technical problems and achieve a production capability competitive with foreign sources.

Another promising trend in ceramics technology which could become very important involves the remarkable advances in the strength of cement and concrete materials which have occurred in recent years. These advances could lead to two important application areas. First, high-strength cement pastes could replace plastics and metals in a variety of applications such as industrial tooling, furniture, roofing and siding, and even, it has been suggested, cafeteria trays.

In the memorandum, on page 27, is a picture of a cement spring, which dramatizes the versatility and resilience of these cement materials.

Second, the increased use of high strength concrete could lead to large savings in maintenance and repair costs in infrastructure projects such as highways and bridges. This opportunity is so significant because the amount of money involved is so large. A recent National Research Council report estimates that over $500 billion will be spent on replacement and repair of highway pavements and bridges by the year 2000. It was also estimated in that report that cost savings of $600 million per year could result from implementing new materials technologies.

However, due largely to the fragmentation of the construction industry, the barriers to the implementation of new materials technologies are very high.

In the next 15 to 20 years, in long-term applications, one might see structural ceramics being used in advanced diesel and gas turbine engines for automobiles. Potential advantages often mentioned

include higher fuel efficiency and the elimination of a cooling system.

Although heat engines have been the most highly publicized potential applications of ceramics, it's not possible to say conclusively at this point that the remaining technical and economic problems will, in fact, be solved. One can say, however, that such engines are not likely to be commercially available before the year 2000, although military versions could be produced sooner. Advances in these applications are likely to be driven by Government funding.

In fiscal year 1986, the Federal Government spent about $60 million on structural ceramics R&D, primarily in the Departments of Energy and Defense, as I have indicated in table 1. Given the spectrum of opportunities, the memorandum suggests a ranking of R&D priorities in order of importance, and among the priorities considered most important for ceramics are developing a strong scientific base to support the manufacturing processes of ceramics and improving their reliability.

When these priorities are compared with actual Federal spending for structural ceramics R&D in fiscal year 1985, a rough agreement is found. However, the comparison suggests a greater emphasis should be placed on standardized testing methods, joining of ceramics to other materials, friction and lubrication properties of ceramics, and cement-based materials.

Polymer matrix composites are essentially plastics which have been reinforced with strong, lightweight fibers, such as graphite, and I have several examples in the box there of graphite-reinforced composites. Chief among the advantages of composites is their light weight coupled with high stiffness and strength. Other very important properties include their resistance to corrosion and fatigue, both of which are superior to metals.

Composites also offer a variety of manufacturing advantages, and perhaps the most important of these is the opportunity to consolidate a large number of components into one component, thus reducing assembly costs. Because composites must compete with inexpensive steel and aluminum alloys, lower manufacturing costs are essential to offset the higher cost of the composite materials.

World-wide sales of advanced composites are projected to grow by about 15 percent annually for the remainder of the century, increasing from a 1985 value of about $1.4 billion to nearly $12 billion by the year 2000. The industry continues to be driven by aerospace markets with military applications likely to grow by as much as 22 percent in the next few years.

Composites are rapidly becoming the baseline materials in high-performance fighter and attack aircraft. The next major challenge for composites will be use in large commercial and military transport aircraft. Composites currently comprise about 3 percent of the structural weight of commercial aircraft such as the Boeing 757 but could eventually count for 65 percent or more.

Since fuel savings are a major reason for the use of composites in commercial aircraft, persistent low fuel prices could delay their exploitation. The largest volume opportunity for composites in the future is clearly in the automobile. Composites are currently in limited production in body panels, drive shafts, and leaf springs,

but by 1995 large portions of the automobile structure could be made of composites.

The principal advantage of composite structural components would be parts consolidation leading to lower assembly costs and reduced tooling costs. If composites were to be used extensively in automobiles, the effects on the way cars are designed, built, and serviced would be dramatic. However, production methods some 10 times faster than current methods will have to be developed in order to take advantage of this opportunity.

Additional applications of composites anticipated in the next 10 to 15 years include medical implants, reciprocating industrial machinery such as robots, storage, and transportation of corrosive chemicals, and military vehicles and weapons.

Beyond the turn of the century, composites could be used in construction applications such as bridges and buildings. This will require cheaper materials and designs which take advantage of the compounding benefits of composites, such as reduced weight and increased durability.

In space, composites will be used in the proposed aerospace plane, and they are being considered for the tubular frame of the NASA space station. Composites of various kinds will be a central feature of space-based weapons systems such as those under consideration for ballistic missile defense.

In fiscal year 1986, the Government spent about $40 million on polymer composites R&D primarily in the Department of Defense and NASA, as indicated in table 2. Polymer composites have achieved an excellent service record, and experience indicates that reliable composite structures can be fabricated. While their performance advantages make advanced composites suitable for military applications, for most commercial applications the costs remain unacceptably high. Before such composites can be used in mature, competitive industries such as the automotive industry, new, low-cost manufacturing technologies must be developed.

Other priorities considered very important and mentioned in the memorandum include improving their resistance to impact damage and learning to control the critical boundary layer between the fiber reinforcement and the polymer matrix. As with ceramics, standardized testing methods must be developed.

In conclusion, advanced structural materials represent evolving technologies which will dramatically affect the U.S. economy. The near-term markets for these materials are large, and the long-term opportunities are just beginning to be recognized.

Although the United States faces stiff international competition for the developing world markets, the United States does possess several strengths which should enable it to excel in this competition. These include a strong university system, a well developed computer and software industry, and the largest domestic market for materials in the world. The challenge to national policy makers is to define a Federal role which facilitates the maximum exploitation of these natural strengths.

[The prepared statement of Dr. Eyring follows:]

TESTIMONY OF GREGORY EYRING
PROJECT DIRECTOR, ENERGY AND MATERIALS PROGRAM
OFFICE OF TECHNOLOGY ASSESSMENT

before

Subcommittee on Transportation, Aviation, and Materials
House Committee on Science and Technology

New Structural Materials Technologies: Opportunities for the Use of Advanced Ceramics and Composites

September 17, 1986

Mr. Chairman,

I appreciate the opportunity to testify at this hearing on the implementation of the National Critical Materials Act of 1984. The Committee on Science and Technology has had a long-standing concern about both strategic materials issues and about the implications of the development of new materials technologies for the competitiveness of U.S. manufacturing industries. At the joint request of this Committee and the Senate Committee on Commerce, Science, and Transportation, the OTA has undertaken two assessments which are relevant to these concerns. The first was a report completed in May, 1985 entitled Strategic Materials: Technologies to Reduce U.S. Import Vulnerability; the second is an ongoing study entitled New Structural Materials Technologies. In conjunction with this hearing, OTA is releasing a Technical Memorandum associated with the latter study called Opportunities for the Use of Advanced Ceramics and Composites. We feel that the findings of this Memorandum are particularly relevant to this hearing today; specifically, to the Council's activities relating to advanced materials.

This Technical Memorandum assesses the opportunities for the use of new structural materials in the next 25 years, outlines the research and development priorities implied by those opportunities, and concludes with a discussion of some key prerequisites for their realization. A discussion of public policy options for accelerating the development and commercialization of advanced structural materials, is deferred until the final report, which should be completed in June of next year. A summary of the Technical Memorandum follows.

The past 25 years have witnessed remarkable developments in structural materials technologies; new nonmetallic materials, such as ceramics and polymer matrix composites, are replacing metals in a wide variety of applications, ranging from cutting tools to tennis rackets. The new materials represent both an opportunity and a challenge for U.S. manufacturing industries. In an era of concern about the long-term economic viability of the manufacturing sector, they open a promising avenue to renewed international competitiveness, new industries, and employment opportunities.

Advanced materials are often ranked with microelectronics and biotechnology as the three most promising "high-tech" industries of the future. It is important to note that in most cases ceramic and composite structures do not stand alone, but are instead components which enhance the performance of much larger systems, such as automobiles or aircraft. Thus, the materials have a significance to the economy extending far beyond the value of the materials themselves.

By the year 2000, large markets for ceramic and composite products will be found in military, aerospace, automotive, medical, and construction applications. However, these opportunities cannot be taken for granted. The United States does not enjoy a comfortable lead (indeed it often lags) in new structural materials technologies; key advances continue to come from abroad. Moreover, through well-coordinated government-industry efforts, several countries have succeeded in bringing ceramic and composite products to the market years in advance of comparable U.S. products. Japan in particular has initiated aggressive programs to commercialize its evolving materials technologies. In order to realize the promise represented by the new materials, U.S. policymakers in government, universities, and industries will have to come together to define feasible goals and materials applications, coordinate research and development efforts toward these goals, and, especially, focus on reducing the barriers to commercial introduction of advanced ceramic and composite products.

Structural materials may be classified as ceramics, polymers, or metals, as shown in Figure 1. Two or more of these materials can be combined together to form a composite having properties superior to those of the constituents alone. The most common form of composite is a host material (matrix) which is reinforced with particles or fibers of a second material. Composites are classified according to their matrix phase; thus, there are ceramic matrix composites (CMCs), polymer matrix composites (PMCs), and metal matrix composites (MMCs). Wood, jade, and

oyster shells are natural composites which display remarkable strength and durability. A common man-made composite is glass fiber reinforced plastic (FRP), which combines the strength of the glass with the toughness and corrosion resistance of plastic. The materials discussed in this Technical Memorandum fall in the shaded categories in Figure 1; ceramics and polymer matrix composites.

The diversity of structural materials available today offers many options to the designer. Typically, a given structure can be fabricated from any of a variety of candidate materials. Only rarely will the performance requirements dictate a single choice. Nor does the challenge to the primacy of metals come only from the most "advanced", most expensive composites or ceramics: unreinforced engineering polymers such as nylons or polyimides, and chemically bonded ceramics (high performance cements) offer an inexpensive and effective alternative to metals in many applications. This capacity for materials substitution complicates the task of projecting the future shares of materials in various markets. However, one can predict with confidence that the properties and manufacturing advantages of ceramics and composites will make them as familiar in the 21st century as metals are today.

In addition to changing the engineering landscape, advanced structural materials have also altered the boundaries of traditional policy concerns relating to materials. Historically, the federal interest in materials has centered around the problem of shortages of

supply of certain "critical" minerals. For example, the United States is dependent on foreign sources for virtually all of its chromium, manganese, cobalt, and platinum group metals. These metals are important ingredients in a variety of steel alloys and superalloys. To a limited extent, ceramics and composites, which are made from plentiful raw materials, can alleviate this problem through substitution.[1] However, the potential of the new materials goes far beyond simple substitution; they provide performance advantages in both military and commercial applications which can not be achieved with metals. Ceramics and composites are now considered to be "critical" in their own right, both for national defense and future economic competitiveness. Therefore, the appropriate federal role in accelerating the development and commercialization of these materials is likely to be a subject of active debate in the years ahead.

The federal government plays two important roles in the research and development of advanced ceramics and composites: one military, and the other non-military. The Department of Defense funds some 35 percent of federal R&D on structural ceramics and about 70 percent of that on polymer matrix composites. The military and non-military agencies have very different funding goals and materials requirements.

1. Strategic Materials: Technologies to Reduce U.S. Import Vulnerability (Washington, D.C.: U.S. Congress, Office of Technology Assessment, OTA-ITE-248, May 1985).

In the case of the military, the government is the customer for materials technology and hardware. It has an interest in securing stable, domestic sources of material supply. Although materials cost is an important consideration, typically the performance advantages obtained are more important. Military applications often provide a first "window" for the use of advanced materials; however, the technologies may or may not be "spun off" into commercial applications. Because of the emphasis on high performance and the fact that production volumes are typically low, often neither the materials nor the production methods are appropriate for commercial applications. For national security reasons, restrictions are placed on the dissemination of DOD-funded research results in scientific publications and at meetings; export controls may also be placed on shipments of the materials abroad. These restrictions tend to further discourage the commercial utilization of materials technologies developed by the military. In the future, demand for high performance materials in such applications as aircraft, missiles, and space-based weapons systems will continue to make these among the fastest growing applications of structural ceramics and composites.

About half of total federal spending for advanced ceramics and polymer matrix composites R&D is non-military in nature, including most of that funded by the Department of Energy, NASA, the National Science Foundation, the National Bureau of Standards, and the Bureau of Mines. Most of these agencies do not act as the procurers of hardware, but instead fund materials research ranging from basic science to technology

demonstration programs, according to their mission objectives. Where appropriate, they openly seek to transfer materials technology to the private sector. For a variety of reasons, the success rate of these efforts has been low: the technology may require significant further development prior to utilization; the market opportunities for the technology may be too long-term or poorly defined; or key decisionmakers within the receiving company may not be committed to commercializing the technology. Federal nonmilitary materials R&D clearly represents a resource which can be exploited more effectively by U.S. companies in the future.

An important policy objective for the future could be to encourage industrial investment in research, development, and commercialization of ceramic and composite materials. Factors discouraging these investments include: fragmentation of industries and markets, which precludes any one segment from undertaking the necessary research; concerns that R&D investments cannot be protected from competitors because of the high transferability of the technologies; and the relatively high cost of capital in the U.S. compared with competitor nations such as Japan. Federal efforts to facilitate collaborative R&D arrangements between industries, universities, and government laboratories, to tighten patent protection for industrial products and processes, and to articulate policy clearly on export controls and on product liability issues, are likely to be very important. Ultimately, however, a strong U.S. competitive position depends on a judgement on the part of manufacturers that the new materials offer cost and performance advantages in the marketplace.

CERAMICS

Ceramics encompass such a broad class of materials that they are more conveniently defined in terms of what they are not, rather than what they are. Accordingly, they may be defined as all solids which are neither metallic nor organic. Compared with metals, ceramics have superior wear resistance, high temperature strength, and chemical stability they also generally have lower electrical and thermal conductivity, and lower toughness. The low toughness of ceramics (brittleness) causes them to fail suddenly when applied stress is sufficient to propagate cracks which originate at microscopic flaws (e.g. cracks, voids, or inclusions as small as 20 micrometers) in the material. The actual stress level at which this occurs can be very high (e.g. 300,000 psi, or 2,069 MPa) and theoretically could be much higher, if flaw sizes could be reduced. Unpredictable failure caused by poor control over flaw populations is the most serious handicap to the use of structural ceramics in load-bearing structures.

Most advanced structural ceramics are fabricated by consolidation of a compact of pure, finely divided oxide or non-oxide powders in a furnace at high temperatures. However, another class of ceramics, called chemically bonded ceramics, develop their strength at room temperature, typically through chemical reactions involving the uptake of water. Traditional cement pastes and concretes fall in this category. Because these materials normally contain large flaws which

limit their strength, they are not ordinarily considered "advanced". However, in recent years the properties of chemically bonded ceramics have improved dramatically as new processing methods have reduced the strength-limiting flaws. High strength cement-based composites could provide a low-cost alternative to metals or plastics in such applications as industrial tooling, paneling, furniture, and roofing. Similarly, use of improved concretes could result in large savings in repair and maintenance costs of infrastructure projects such as highway pavements and bridge decking.

MARKET OPPORTUNITIES FOR CERAMICS

Market demand for structural ceramics is not driving their development in most applications at the present time. In 1983, the world market for advanced structural ceramics was estimated as $250 million, primarily in heat and wear-resistant applications. Projections to the year 2000 place the U.S. market variously between $1 and $5 billion, spread among many new applications discussed below. The larger estimates assume substantial utilization of ceramics in automotive heat engines, long predicted to be the most important application of structural ceramics. OTA projects that significant use of structural ceramics in automotive heat engines is not likely by the year 2000. However, large near-term opportunities are available in other products, such as medical devices.

Japan is the principal competitor to the United States in advanced ceramics technology. Japanese companies have made a long-term commitment to the development of advanced ceramics which looks beyond the current weak market demand. They have mounted a well-coordinated effort which includes: increasing the quality and availability of raw materials; optimizing fabrication processes; installing the most advanced processing and quality control equipment; initiating manufacturing development; and aggressive marketing of evolving materials. This commitment to the future of ceramics is likely to give Japanese companies the early lead in capturing the large near-term markets.

Current Production

Ceramics such as alumina, silicon nitride, and silicon carbide are in production for wear parts, cutting tools, bearings, and coatings. The market share for ceramics in these applications is generally less than 5%, but substantial growth is expected, and the U.S. markets for the ceramic components alone could be over $2 billion by the year 2000. Research and development funding is currently being provided by industry and is driven by competition in a known market.

Ceramics are also in limited production (in Japan) in discrete engine components such as turbochargers, glow plugs, and precombustion chambers. Current military applications include radomes, armor, infrared windows, and heat sources.

Near-Term Production

Near term production (next 10-15 years) is expected in advanced bearings, bioceramics, construction applications, heat exchangers, electrochemical devices, discrete components in automobile engines, and military applications. The technology feasibility has generally been demonstrated, but scale-up, cost reduction, and design optimization are required. Large markets are at stake: especially promising are bioceramics for dental and orthopedic implants, and chemically bonded ceramics for construction applications. In many cases, government funding could help to solve the remaining problems and achieve a production capability competitive with foreign sources.

Long-Term Applications

Long-term applications (beyond 15 years) are those which require solution of major technical and economic problems. These include an advanced automotive turbine engine, the advanced ceramic diesel (although ceramics could be used in military versions of these engines at an earlier date), some electrochemical devices, military components, and heat exchangers. A variety of other turbine engines, especially turbines for aircraft propulsion and for utility-scale power generation, should also be categorized as long-term. In general, the risks are perceived by U.S. industry to be too high to justify funding the needed research. Advances in these applications are likely to be driven by government funding.

RESEARCH AND DEVELOPMENT PRIORITIES

In Fiscal Year 1986, the federal government spent about $60 million on structural ceramics research and development, as shown in Table 1. R&D expenditures in private industry are estimated to be roughly comparable. The Departments of Energy and Defense spent the largest fractions, at 47% and 36%, respectively.

The following hierarchy of R&D priorities is based on the technical barriers which must be overcome before ceramics can be used in the applications discussed above.

Very Important

Processing Science: This is the key to understanding how processing variables such as temperature, composition, and particle size distribution are connected to the desired final properties of the ceramic.

Environmental Behavior: In many applications, ceramics are required to withstand high temperature, corrosive, or erosive environments. Information on the long term behavior of ceramics in these environments is essential to predict the service life of ceramics in those applications.

Reliability: The reliability of advanced ceramics and ceramic composites is the single most important determinant of success in any application. Progress requires advances in brittle materials design, process control, nondestructive evaluation, understanding crack growth processes, and life prediction.

Ceramic Composites: These novel materials offer an exciting opportunity to increase the strength and toughness of ceramics.

Important

Joining: Joining of ceramics to metals, glasses, and other ceramics is necessary when ceramic components are incorporated into larger systems. The principles developed in joining research can also be applied to coating technology.

Tribology: This is the study of friction, wear, and lubrication of surfaces in relative motion. It is especially relevant to understanding the degradation of ceramic wear parts, bearings, and the lubrication requirements of high temperature ceramic engines.

Standardization and Testing: Although standards exist for ceramic refractories and brick, at present there is a lack of standards for advanced ceramics, whether for testing procedures, compositions, or processing history. Such standards are a prerequisite for confident design and industry acceptance of ceramics.

Desirable

Chemically Bonded Ceramics: These materials, which include advanced cement pastes and concretes, represent an outstanding potential for low-cost, net shape fabrication of ceramic structures. The cost savings associated with the use of improved concretes in highways and bridges are likely to be very large compared with the research investment required.

POLYMER MATRIX COMPOSITES

Polymer matrix composites are organic polymers which have been reinforced with a variety of short or continuous fibers to provide added strength and stiffness. The composite is designed so that the mechanical loads to which the structure is subjected in service are supported by the reinforcement. The amount of reinforcement and its geometry can be varied across the structure, resulting in highly efficient use of material, consolidation of parts, and weight savings.

Chief among the advantages of polymer composites is their light weight coupled with high stiffness and strength along the direction of the reinforcement. This combination is the basis of their usefulness in aircraft, automobiles, and other moving structures. Other desirable

properties include corrosion and fatigue resistance. One generic limitation of polymer matrix composites is temperature; an upper limit for service temperatures with present composites is about 600 F (316 C). With additional development, temperatures above 800 F (427 C) might be achieved.

In addition to their superior physical and mechanical properties, polymer composites offer many design and manufacturing advantages. Perhaps the most important of these is the opportunity to consolidate a large number of parts into one, thus reducing assembly costs. This capability has already been demonstrated in aircraft and automotive applications.

MARKET OPPORTUNITIES FOR POLYMER MATRIX COMPOSITES

Fiberglass composites have been in use since the 1940's, and about 85% of the materials used in the reinforced plastics/composites industry today are glass fiber reinforced polyester resins. Less than 1.5% of the materials are "advanced" composites such as those used in aircraft and aerospace. Worldwide sales of advanced composites have been projected to grow by 15% annually for the remainder of the century, increasing from a 1985 value of $1.4 billion to nearly $12 billion by the year 2000. The industry continues to be driven by aerospace markets, with defense applications likely to grow by as much as 22% per year in the next few years.

Current Production

Aerospace applications of polymer composites account for about 60% of current sales. Sporting goods, such as golf clubs and tennis rackets, account for another 20%. The sporting goods market is considered mature, with projected annual growth rates of 3%. Automobiles and industrial equipment round out the current list of major users of advanced composites, with a 15% share.

Near-Term Production

Composites were introduced into the horizontal stabilizer of the F-14 fighter in 1970, and have now become the baseline materials in high performance fighter and attack aircraft. The next major challenge for composites will be use in large military and commercial transport aircraft. Composites currently comprise about 3% of the structural weight of commercial aircraft such as the Boeing 757, but could eventually account for more than 65%. No technical barriers are foreseen which might prevent this scenario, although design and certification databases for civil applications need to be established. Since fuel savings are a major reason for the use of composites in commercial aircraft, continued low fuel prices could delay their exploitation.

The largest volume opportunity for polymer composites is in the automobile. Composites currently are in limited production in body panels, drive shafts, and leaf springs. By 1995, composite unibody frames could be introduced in limited production. The principle advantage of a composite frame would be the potential for parts consolidation resulting in lower assembly costs. If composites were to be used extensively in frames, the effects on the way automobiles are designed, built, and serviced would be dramatic. However, production methods some 10 times faster than current methods will have to be developed in order to take advantage of this opportunity.

Additional near-term markets for polymer composites include medical implants, reciprocating industrial machinery, storage and transportation of corrosive chemicals, and military vehicles and weapons.

Long-Term Applications

Beyond the turn of the century, composites could be used extensively in construction applications such as bridges, buildings, and manufactured housing. Realization of this opportunity will depend on development of cheaper materials and on designs which take advantage of compounding benefits of composites, such as reduced weight and increased durability. In space, a variety of composites will be used in the proposed aerospace plane, and composites are being considered for the tubular frame of the space station. Composites of all kinds, including

metal matrix, ceramic matrix, and polymer matrix, will be a central feature of space-based weapons systems such as those under consideration for ballistic missile defense.

RESEARCH AND DEVELOPMENT PRIORITIES

Federal R&D spending for polymer matrix composites in Fiscal Year 1986 was about $41 million, as shown in Table 2; the Department of Defense and NASA accounted for the lion's share, at 71% and 21%, respectively. Total private sector R&D spending is not known, but is certainly much higher.

Polymer matrix composites have achieved an excellent service record and experience indicates that reliable composite structures can be fabricated. However, in many cases the technology has outrun the basic understanding of these materials. In order to generate improved materials and to design and manufacture composites more cost-effectively, the following needs should be addressed.

Very Important

Processing Science: Development of new, low cost fabrication methods will be critical for composites. An essential prerequisite to this is a sound scientific basis for understanding how process variables affect final properties.

Impact Resistance: This property is crucial to the reliability and durability of composite structures.

Delamination: A growing body of evidence suggests that this is the single most important mode of damage propagation.

Interphase: The poorly understood interfacial region between the fiber and matrix has a critical influence on composite behavior.

Important

Mechanical Properties: Better scientific understanding and modeling in the following areas would permit development of better materials and improved designs: strength, fatigue, and fracture.

Environmental Effects: The environments that composites are subjected to can have a deleterious effect on their long-term reliability. Investigation of the effects of moisture and temperature are particularly important.

Reinforcement Forms and Hybrid Composites: Innovations in both of these areas would provide opportunities to improve properties and reduce costs. The large number of variables makes a purely empirical approach very inefficient.

Test Methods: Lack of standardized test methods contributes to the considerable variability in reported property values.

Desirable

Viscoelastic and Creep Properties: Deformation resulting from sustained loading can have an adverse effect on structural performance. A greater database is required, especially for compressive loading.

GENERAL PREREQUISITES FOR THE USE OF ADVANCED STRUCTURAL MATERIALS

Education and Training

At present, the demand for scientists and engineers trained in ceramics and composites technologies outstrips the supply. Education may be the most effective tool available to government for accelerating the development of advanced materials in the long run. Several aspects should be considered. Undergraduate introductory courses in ceramics and composites should be offered to engineering majors. Undergraduate courses specializing in design with these materials should also be available to all students in applied mechanics, including mechanical and civil engineers. Provision should be made through seminars and short courses for continuing education of engineers in other areas who want to learn more about ceramics and composites. Also, education of designers,

planners, managers, and the general public through newspapers, magazines, and television will be especially important in creating demand for products made from these high technology materials.

Multidisciplinary Approach

In recent years there has been an increasing appreciation of the fact that many problems in science and technology are most effectively solved through the combined efforts of specialists from a variety of disciplines. In no case is this more apparent than with advanced materials. The nature of ceramics and composites is such that the process which transforms the raw materials into the finished product integrates the discrete steps of design, manufacturing, and testing into a coherent whole. The familiar distinctions between the product and the material from which it is made become blurred, in a way which is qualitatively different from our experience with traditional materials. This integrative property implies that a multidisciplinary team of experts is more likely to solve the problems associated with the development and application of advanced materials than an alternative approach involving individual researchers.

Integrated Design

The outstanding opportunities presented by ceramics and composites do not lie in part-for-part replacement of metal in current designs; rather, new designs which incorporate many parts and functions

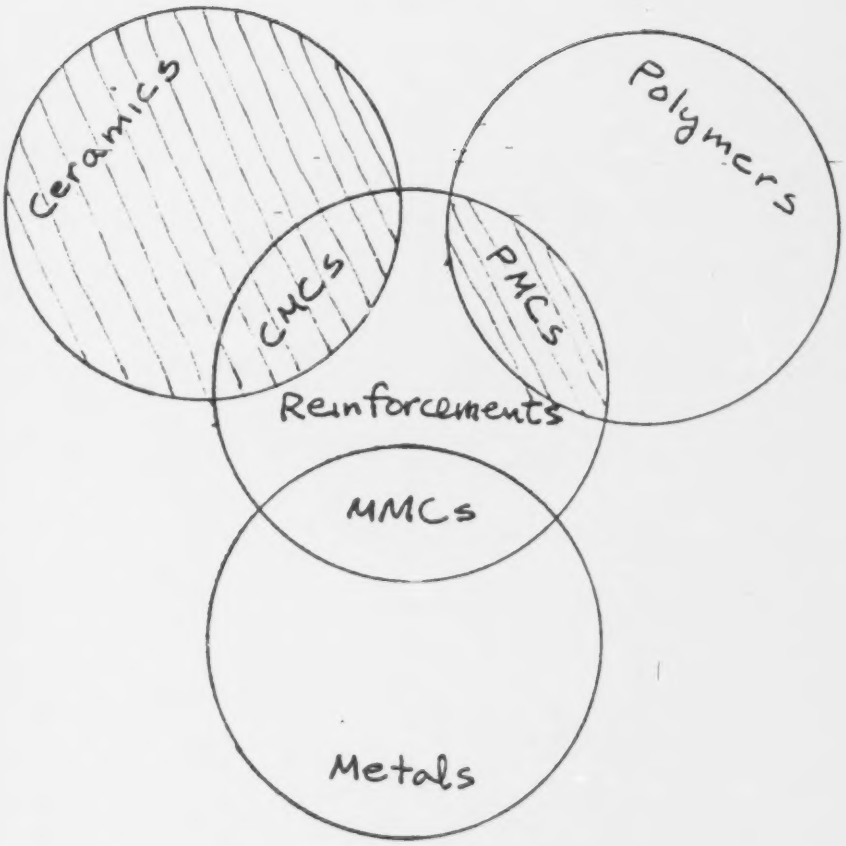
into one are made possible. These new structural shapes and systems for carrying loads may not look at all like metal designs. Such a design capability will require the development of sophisticated software for computer modeling and analysis, as well as an extensive database on materials properties. Perhaps the most important requirement is for a better scientific understanding of how the properties of the microscopic constituents determine the overall behavior of the structure. Many of the research and development priorities above are aimed at providing this information.

Systems Approach to Costs

High cost is often cited as the largest barrier to the use of advanced ceramics and composites. Indeed, on a dollar-per-pound basis, today's ceramics and composites often cost several times as much as the materials they would replace. Although costs can be expected to decline as production volumes increase and manufacturing technologies mature, the baseline costs per pound of many ceramics and composites may always be higher than those of steel and aluminum. However, rather than a barrier, cost may in fact be a potential advantage of the new materials, if the "system costs", including materials, manufacturing, and life cycle maintenance of a structure, are all taken into account. Like multidisciplinary research and integrated design, a systems approach to costs is implied by the holistic nature of advanced materials.

In conclusion, advanced structural materials represent evolving technologies which will dramatically affect the U.S. economy. The near-term markets for these materials are large, and the long-term opportunities are just beginning to be recognized. Although the United States faces stiff international competition for the developing world markets, the U.S. does possess several natural strengths which should enable it to excel in this competition. These include a strong university system, a well developed computer and software industry, and the largest domestic market for materials in the world. The challenge to national policymakers is to define a federal role which facilitates the maximum exploitation of these natural strengths.

Figure 1



The family of structural materials includes ceramics, polymers, and metals. Reinforcements added to these materials produce ceramic matrix composites (CMCs), polymer matrix composites (PMCs), and metal matrix composites (MMCs). Materials in the shaded regions are discussed in this report.

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Table 1. —Structural Ceramic Technology: Federal Government Funded R&D (in millions of dollars)

	FY 1983	FY 1984	FY 1985	FY 1986	Estimated FY 1987
Department of Energy:					
Conservation and renewable energy:					
Vehicle propulsion	11.4	12.7	11.9	10.0	5.2
Advanced materials	3.2	5.1	6.0	8.7	6.5
Industrial programs	1.0	2.3	1.7	1.5	0.8
Energy utilization research	0.5	1.5	1.8	1.8	1.0
Fossil energy:					
Advanced research and technology development	1.0	1.1	1.5	1.2	0.9
Energy research:					
Basic energy science	3.0	4.4	4.6	4.5	4.5
NASA:					
Lewis Research Center	3.0	2.5	5.4	4.5[a]	4.6[a]
National Science Foundation	2.9	3.3	3.6	3.6	3.7
National Bureau of Standards				2.2	3.0
Department of Defense:					
Defense ARPA	7.7	8.2	9.4	10.0	5.0
U.S. Air Force	3.0	3.4	4.7	4.7	5.0
U.S. Army	4.7	6.0	2.5	4.4[b]	4.7[b]
U.S. Navy	1.2	1.3	1.4	2.3	2.3
Total	42.6	5 .8	54.5	59.4	47.2

[a]Includes $1.8 for Manpower Salaries.
[b]Includes $4.0 for TACOM Diesel.

SOURCE: Robert B. Schulz, Department of Energy.

Table 2.—Budgets for Polymer Matrix Composite R&D in Fiscal Years 1985 and 1986 (millions)

Agency	FY 1985	FY 1986
Department of Defense[a] (6.1, 6.2, 6.3A)	55.9	29.2
National Aeronautics Space Agency[b]	23	8.7
National Science Foundation[c]	1-2	1-2
National Bureau of Standards[d]	0.4	0.4
Department of Transportation[e]	—	0.5
Total	80-81	40-41

SOURCES: [a]Jerome Persh, OSD
[b]Michael Greenfield, NASA
[c]Ranga Komanduri, NSF
[d]Leslie Smith, NBS
[e]Craig Ballinger, FHWA

Mr. BROWN. Thank you very much, Dr. Eyring. Your statement and the report are really quite exciting, and we appreciate your submitting them for the subcommittee.

You make one statement here that intrigues me a little bit. You say, "Before advanced composites can be used in mature, competitive industry, such as the automotive industry, new, low-cost manufacturing technologies must be developed." Give us an idea of what the prospects are for the development of such new manufacturing technologies. We're very much interested in this subcommittee also in maintaining our competitive position in manufacturing technology. We see many signs throughout industry that we've been lagging in this area and wondered if your analysis might have indicated what direction we might go in order to achieve this capability that you're talking about.

Dr. EYRING. Advanced design teams in Detroit are currently looking at a series of such technologies for the manufacture of the chassis-body combination of the automobile in perhaps one part or perhaps two or three parts made of composite where now it consists of hundreds of parts.

The exact technology which will eventually be chosen has not yet been determined. However, most advanced composites now which are used in aircraft are essentially laid up by hand. You have many, many workers laying layer by layer of composite on top of one another, and such technologies are clearly inappropriate for an industry like the automobile industry which must manufacture parts in the order of seconds and minutes and not hours, days, and weeks.

Mr. BROWN. Are some of the new manufacturing plants in the automotive industry, such as the one that General Motors is building out in California, incorporating some of these new manufacturing technologies, or are they merely applying automation to existing manufacturing problems, if I can try and make a rough difference there?

Dr. EYRING. There are no current production facilities for large-scale use of structural components of composites. General Motors had been taking a lead in the industry in the use of composites in the external skin of the automobile, and the Pontiac Fiero is the most recent and visible example of that. However, in the last couple of months GM has made a business decision to pull back from its aggressive program in this area. It had been planning to use the composite skins on a variety of models in the 1990's, including the Camaro and others, and it has recently decided to go back and use steel for those.

Mr. BROWN. Is that due to the price decline in steel?

Dr. EYRING. I am not privy to all the reasons for that decision.

Mr. BROWN. I won't pursue that point.

Mr. Packard, do you have some questions?

Dr. BLAIR. Mr. Brown, I might add that OTA has just initiated a new assessment of manufacturing technologies, and this is liable to be a very prominent issue in that assessment.

Mr. BROWN. What is the status of that assessment?

Dr. BLAIR. It was just approved by the board at the last meeting, as I recall.

Mr. BROWN. All right. You haven't completed it then?

Dr. BLAIR. No—just initiated.
Mr. BROWN. All right.
Mr. Packard.
Mr. PACKARD. Thank you, Mr. Chairman.

There's a great deal of transfer of information from one industry to another and often would relieve—if there's a good articulation of that information from one industry to another in their research processes would often relieve reinventing the wheel by each industry. What vehicles and what agencies assist in doing this?

I think of my own industry. I came out of the dental field, and a great deal of composites for years have been researched in dental research in crowns, bridges, implants, as you mentioned, and of course composite filling materials, highly controlled by virtue of expansion-contraction ratios that are required to correspond to that of the two-structure or other conditions. Much of that ability to control contraction-expansion ratios of different filling materials and other materials that are used in the mouth came out of the aerospace industry by chance, not by coordinated, planned articulation of sharing that information.

That's a simple example, but there are, I'm sure, multitudes of examples where the automobile industry could share with the aerospace industry and information in the biomedical industry, et cetera, et cetera. What is being done, and what agencies assist in articulating that information from one industry to another?

Dr. EYRING. Well, as I agree with you, this is an extremely important area of focus for the future, and it is an area that OTA will look at very carefully as we continue in this study in the next few months.

There are currently a wide variety of programs, for example, in the national laboratories at Oak Ridge, at Argonne, at the National Bureau of Standards, and so on, in which ceramic research is being shared and is being done collaboratively with a variety of industries. This is an area that much more attention needs to be paid to in the future.

Mr. PACKARD. I agree with your statement in the early part of your testimony where you say that perhaps the three most promising high technolgy industries of the future are biotechnology, information technology, and, of course, the advanced materials technology which we're talking about.

Certainly in the fields that I've been associated with, materials has played probably a more vital role in change and in improvement than technique or than any other area, and I see that coming down the road in a multitude of other areas, and certainly information technology—I think you've really struck there—as a very critical area.

I think that there has to be an articulation between those two; otherwise, the cost of materials will be increased simply because we have not looked for ways to share information and technology, and that perhaps is particularly true in military areas. We do spend, I think, probably more money, Government money, in military research and development in these areas than any other single field as far as Government funds. Private funds, of course, may be different, but in Government funds a good deal of our

budget is in military technology and military investigation and research.

What are we doing in that area to correlate? I would not assume that OTA has as much involvement in military activities as they would perhaps in more of the private sector or in nonmilitary research. Is that true, and, if so, what can be done to bridge that informational gap?

Dr. EYRING. Military applications often provide a first window for the use of new structural materials. In the military, the emphasis is typically on the performance of the materials more than the cost, and for that reason and because production volumes are typically very low, the technologies that are developed in the military are frequently inappropriate for use in applications such as the automobile which requires mass production and very low-cost materials.

An additional problem with transferring technology from the military are restrictions that the DOD puts on the dissemination of information relating to advanced materials research and other factors, such as export controls, that they put on controlling the export of products made from new materials to certain other countries, and all of these factors have made private industry rather leery of working with the Department of Defense on new materials development for commercial application.

Mr. PACKARD. In your judgment, is the DOD overly sensitive to the detriment of informational exchange, or are we protecting information under the guise of military secrecy and military protectionism? In your judgment, do you believe that we could share some of that information without jeopardizing national security?

Dr. EYRING. That's a very difficult question to answer in a quantitative way. I believe there is an ongoing study on that very subject being done now by the Congressional Research Service.

The DOD has its own mission. It develops materials to provide for the national defense, and its primary intention is not then to go and transfer those materials to the commercial sector.

I think there may be reasons to think that these issues should be looked at very carefully in terms of the chilling effect that they may have on private industry investment.

Mr. PACKARD. Thank you very much, Mr. Chairman.

Mr. BROWN. Dr. Eyring, getting back to the Critical Materials Council for a moment, one of its roles is that of trying to establish appropriate priorities for the expenditure of Federal R&D funds, and noting the R&D priorities that you've suggested in your report, I wonder if you could give us any indications as to how these priorities are matched by our ongoing Federal R&D or industry R&D efforts.

Dr. EYRING. In the report, we did compare information that was made available to us by the Department of Energy on actual spending for structural ceramics in fiscal year 1985, and we compared that actual spending with our suggested R&D priorities, and we found a general broad agreement, and I've noted in my testimony a few areas where we felt that additional emphasis should be placed.

That kind of data was not available for polymer composites, although I think one can make the general observation that if we intend to have these materials available for commercial use in

mass production kinds of environments, we really need to focus very carefully on low-cost production methods in particular.

Mr. BROWN. Are you suggesting the need to integrate our Federal research efforts in advanced materials with our support for research in manufacturing technologies as an appropriate reinforcing way of solving some of our competitiveness problems?

Dr. EYRING. A key aspect of the development of new materials, new structural materials in general, is this area of processing and manufacturing, because that is where the properties of the final product are determined. So it's very important to integrate production and manufacturing aspects with more basic R&D.

Mr. BROWN. We have had testimony from industry representatives that they feel that the scope of Federal support should extend beyond merely basic research to a proof of concept phase. Do you believe that this is an appropriate role for the Federal Government to move in that direction, or should we continue to restrict the Federal efforts to what might be called just the basic research phase of this?

I'm thinking roughly here of the categories that the Defense Department uses for budgetary purposes, the 6.1, 6.2, 6.3. Of course, in the military where they are the customer, they proceed to the proof of concept phase, but we do not have anywhere near that, in general, in the civilian sector. This is a policy question, and I don't want you to get too deeply involved, but you might give us a personal view on it.

Dr. EYRING. I think the answer to that depends on the kind of application for the material that one is talking about. There are certainly applications such as cutting tools and coatings in which industry is certainly in a position to take very basic kinds of R&D and run with it and invest their own R&D funds because the payoffs for those kinds of technologies are very clear and they're really here today.

Mr. BROWN. The market is already here.

Dr. EYRING. Right.

Mr. BROWN. OK.

Dr. EYRING. There are other kinds of applications in which the risks are considered high and the payoffs are considered long term, and in these kinds of applications I think there is an appropriate Government role in collaboration with industry and with universities. This question of collaboration was mentioned to us many times in our interviews with people in the process of preparing this report, and this is a very important area for focus in the future.

Mr. BROWN. We've found in many areas in federally supported R&D that there are some very serious policy differences in situations where there is an already established large-scale market, on the one hand, and, on the other hand, where there is a promising development for which there has not yet been established a substantial market, and the two do require different approaches.

Unfortunately, there does not seem to have been a great deal of analysis within the Federal Government as to these distinctions and how to change policy in response to that. That's my observation. I would ask you to comment on it if you have any views on that.

Dr. EYRING. I think that's accurate.

Mr. BROWN. I think we have no further questions at this point, and I will express my appreciation again to you for your contribution. We expect to make further use of your report, and I want to assure you how helpful it has been, and we'll continue to call on you for further help.

Dr. EYRING. Thank you.

Dr. BLAIR. Thank you.

Mr. BROWN. Our next witnesses this morning will be representative of the private sector. I'd like to call the next witnesses as a panel: Dr. James Ford, president of the Federation of Materials Societies; Dr. Jonathan Hinton, who is chairman of the Government Affairs Committee of the Advanced Ceramics Association, who is accompanied by Mr. John Coppola, manager of Advanced Programs in Structural Ceramics for Standard Oil.

If you gentlemen can all come up to the table, why, we'll move along expeditiously.

Mr BROWN. Do you need the slide projector?

Dr. HINTON. Yes.

Mr. BROWN. That's fine. Have you got an operator?

Dr. HINTON. Yes.

Mr. BROWN. You're fully staffed to, accomplish your mission then.

Dr. FORD. Yes. I believe we have everything we need.

Mr. BROWN. Dr. Ford, I called your name first. Do you want to go first?

Dr. FORD. That's fine—whatever.

Mr. BROWN. I mean, I'm flexible here.

Dr. FORD. So are we, and I'll go ahead and go first.

Mr. BROWN. OK. You may proceed.

STATEMENTS OF JAMES FORD, PRESIDENT, FEDERATION OF MATERIALS SOCIETIES, AND JONATHAN W. HINTON, CHAIRMAN, GOVERNMENT AFFAIRS COMMITTEE, U.S. ADVANCED CERAMICS ASSOCIATION; ACCOMPANIED BY JOHN A. COPPOLA, MANAGER, ADVANCED PROGRAMS, STRUCTURAL CERAMICS DIVISION, STANDARD OIL ENGINEERED MATERIALS CO.

Dr. FORD. Mr. Chairman, before I begin the written testimony, I'd like to say that coming at this point in time in the testimony, there have been a lot of points made this morning that you'll hear reiterated at least in my testimony and I assume in other testimony from this panel. I hope you will bear with us in that reiteration and view it as reenforcing the needs and ideas that have come from the materials community for the Council's agenda.

Mr. BROWN. We seem to find that there are some situations in which constant reiteration is necessary. You may proceed to constantly reiterate some of these things.

Dr. FORD. Yes, sir.

Mr. Chairman and members of the subcommittee, I am James A. Ford, president of the Federation of Materials Societies. The federation is a unique consortium of organizations whose constituencies include scientists, engineers, and other professionals active in the areas of materials R&D, processing, manufacturing, recovery, resource availability, and policy. Its mission is to identify material

issues and opportunities and to provide the most effective mechanism for cooperative interaction between academia, industry, Government, and the general public. Statements issued by FMS do not purport to speak for the individual member societies.

I appreciate the opportunity to appear before you today at your request and to report on the conclusions and recommendations of the workshop participants at the Ninth Biennial Conference on Nationals Materials Policy held last month in Fredericksburg, VA. The biennial conferences sponsored by FMS have consistently pointed to the need for a coherent national materials policy. The 1984 and 1986 conferences as well as a separate workshop on electronic materials held in February of this year have focused on the role of materials and materials processing technologies in U.S. international competitiveness.

Mr. Chairman, as you know, I sat in this same seat 11 months ago and suggested an agenda for the then nonexistent National Critical Materials Council based on the recommendation of our eighth biennial conference. We repeated those recommendations at the newly created Council's first meeting on January 14 of this year. We have met with the Council's Executive Director, Brien Benson, to refine these and other agenda recommendations and have offered to serve as a conduit between the Council and the materials community.

Our agenda of October 8, 1985, remains as valid today as it was almost a year ago. Yet we see little progress in implementing programs to address its issues. I won't reiterate that agenda except to quote one major concern raised in my previous testimony, a concern which participants in our subsequent conferences have identified as an increasingly critical problem. That is,

> The lack of comprehensive planning and coordination among Federal research and development programs in materials science and engineering and the consequent inability of the Nation, Government, along with industry and academia, to put together a comprehensive materials R&D package with subsequent obvious implications related to international competitiveness.

One of the primary roles of the National Critical Materials Council is to foster that planning and coordination and enhance awareness across both the public and private sector of the leverage provided by investments in materials and material processing R&D, and I emphasize material processing. Indeed, the priority issues identified for the Council in informal meetings of various sectors of the materials community are materials processing, advanced materials, policy coordination in regulatory environment, and public education, all items that were mentioned this morning.

These needs were recurring themes of the Ninth Biennial Conference on Materials Policy whose title was "Advanced Manufacturing and Materials in International Competitiveness." Conference participants were provided an analysis of existing competitive assessments of the automotive, the heavy industrial equipment, the aircraft, the industrial components, and materials producing industries, and considered the conclusions of the earlier FMS conference on electronic materials. Workshops on each of the industries then developed recommendations for industry, Government, and university actions to enhance U.S. industrial competitiveness through ma-

terials and materials processing innovation and integration with manufacturing.

Echoing throughout those parts of the deliberations dealing with the most productive role of Government was the imperative to work closely with industry, academia, and professional groups in determining appropriate priorities for research and development. Other recommendations for Government actions included, first, expand opportunities for collaborative R&D efforts through industry—within industry as well as between industry and Government; two, identify other impediments created by Government actions to innovative uses of materials for increased competitiveness, such as tax policies, trade laws, and the like; three, in close collaboration with industry, academia, and technical societies, explore the development of advanced materials property data systems, and I will add at this point that the example of the cooperation between NBS, the American Ceramics Society, NACE, and ASM in their database work is a classic example of that kind of cooperation; four, consider funding centers for the developments of materials manufacturing and processing technology; and, five, recognize the importance of materials processing, again underlined, to both advanced and basic materials, adopting the perspective that the Government can contribute to competitiveness by becoming more involved in organizing national material resources as well as by providing seed money for material processing development.

The Government can become usefully involved in organizing and coordinating interaction among academia, industry, and Government laboratories, again, a point that has been made. The Government should not legislate priorities, but it could usefully facilitate and coordinate—and encourage coordination.

Again, I'd like to depart from my written testimony to emphasize this question about materials processing. The electronics materials conference held in February clearly showed that, while we have adequate basic R&D, we are not implementing through commercialization those basic findings. There is no silicon power rectification processing being done in this country today, and yet we led the world in that technology. Japan has taken it away from us by effectively developing the processing technology to be more competitive.

Mr. Chairman, these are the recommendations of individuals from industry, academia, and Government at conferences sponsored by FMS, and we offer them as part of the agenda for the National Critical Materials Council.

I'd like to make a summary comment that was the leading theme for the electronics materials conference, and it's a quote from Ben Franklin's Poor Richard's Almanac, and it is, "For want of a nail, the shoe was lost. For want of a shoe, the horse was lost. For want of a horse, the rider was lost." Materials are the nail of our economy, and without adequate national policy we could well lose the horse.

Thank you, Mr. Chairman.

[The statement of Dr. Ford follows:]

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STATEMENT OF JAMES A. FORD
PRESIDENT, FEDERATION OF MATERIALS SOCIETIES
BEFORE THE
SUBCOMMITTEE ON TRANSPORTATION AND MATERIALS
HOUSE COMMITTEE ON SCIENCE AND TECHNOLOGY
September 17, 1986

Mr. Chairman and members of the Subcommittee, I am James A. Ford, President of the Federation of Materials Societies. The Federation is a unique consortium of organizations whose constituencies include scientists, engineers, and other professionals active in the areas of materials R&D, processing, manufacturing, recovery, resource availability and policy. Its mission is to identify materials issues and opportunities and to provide the most effective mechanism for cooperative interaction among academia, industry, government and the general public. Statements issued by FMS do not purport to speak for the individual member societies.

I appreciate the opportunity to appear before you today at your request to report on the conclusions and recommendations of the workshop participants at the 9th Biennial Conference on National Materials Policy held last month in Fredericksburg, Virginia. The biennial conferences sponsored by FMS have consistently pointed to the need for a coherent national materials policy. The 1984 and 1986 conferences, as well as a separate workshop on electronic materials held in February of this year, have focused on the role of materials and materials processing technologies in U.S. international competitiveness.

Mr. Chairman, as you know I sat in this same seat eleven months ago and suggested an agenda for the then-nonexistent National Critical Materials Council based on the recommendations of our 8th Biennial Conference. We repeated those recommendations at the newly created Council's first meeting on January 14 of this year. We have met with the Council's executive director, Brien Benson, to refine these and other agenda recommendations, and have offered to serve as a conduit between the Council and the materials community. Our agenda of October 8, 1985, remains as valid today as it was almost a

year ago -- yet we see little progress in implementing programs to address its issues. I won't reiterate that agenda except to quote one major concern raised in my previous testimony. A concern which participants in our subsequent conferences have identified as an increasingly critical problem. That is "the lack of comprehensive planning and coordination among federal research and development programs in materials science and engineering, and the consequent inability of the nation -- government along with industry and academia -- to put together a comprehensive materials R&D package, with obvious implications related to international competitiveness." One of the primary roles of the National Critical Materials Council is to foster that planning and coordination and enhance awareness across both the public and private sectors of the leverage provided by investment in materials and **materials processing** R&D. Indeed, the priority issues identified for the Council in informal meetings of various sectors of the materials community are materials processing, advanced materials, policy coordination in the regulatory environment, and public education.

These needs were recurring themes of the 9th Biennial Conference on National Materials Policy, whose title was "Advanced Manufacturing, Materials and International Competitiveness." Conference participants considered existing competitive assessments of the automotive, heavy industrial equipment, aircraft, industrial components, and materials producing industries, and considered the conclusions of the earlier FMS conference on electronic materials and materials processes. Workshops on each of the industries then developed recommendations for industry, government and university actions to enhance U.S. international competitiveness through materials and materials processing innovation and integration with manufacturing.

Echoing throughout the deliberations on the most productive role of government was the imperative to work closely with industry, academia, and professional groups in determining appropriate priorities for research and development. Other recommendations for government actions included:

- Expand opportunities for collaborative R&D efforts within industry

as well as between industry and government;

- Identify other impediments created by government actions to innovative uses of materials for increased competitiveness, such as tax policies, trade laws, etc.
- In close collaboration with industry, academia, and technical societies, explore the development of advanced materials property data systems;
- Consider funding centers for the development of materials manufacturing and processing technology;
- Recognize the importance of materials processing to both advanced and basic materials, adopting the perspective that the government can contribute to competitiveness by becoming involved in organizing national materials resources as well as by providing seed money for materials processing development. The government can become usefully involved in organizing and coordinating interaction among academia, industry, and government laboratories. The government should not legislate priorities, but it could usefully facilitate and encourage coordination.

Mr. Chairman, these are the recommendations of individuals from industry, academia and government at conferences sponsored by the Federation of Materials Societies, which we offer as part of the agenda for the National Critical Materials Council. As a summary comment, we would like to leave you with a quote from Ben Franklin's "Poor Richard's Almanac," which served as the maxim for our electronic materials workshop and which reminds us of the importance of materials and materials processing as enabling technologies:

"For want of a nail the shoe was lost.
For want of a shoe the horse was lost.
For want of a horse the rider was lost."

Mr. BROWN. Thank you very much, Dr. Ford.

I'm going to ask you to go ahead, Dr. Hinton, and then we'll have questions for both of you.

Dr. HINTON. Thank you, Mr. Chairman, and members of the subcommittee.

My name is Jonathan Hinton, and I'm vice president and general manager of the Structural Ceramics Division of Standard Oil Engineered Materials Co., but today I'm here addressing you as the chairman of the Government Affairs Committee of the U.S. Advanced Ceramics Association known as USACA.

I'm pleased to have this opportunity to discuss USACA's views on the implementation of the 1984 National Critical Materials Act by the Critical Materials Council. My testimony will focus on the Federal program plan as it relates to advanced ceramic research and development and the importance of such research and development to the United States.

In the interests of time today, Mr. Chairman, I would like to summarize my remarks for the committee and use a few graphics to represent them, but I would respectfully request that the written statement that I submitted be included in its entirety in the official record of this hearing.

Mr. BROWN. It will be made a part of the record in its entirety, Dr. Hinton.

Dr. HINTON. Thank you.

Joining me today as projectionist and otherwise expert, Dr. John Coppola, manager of advanced programs for our company. Dr. Coppola has recently returned from a three-year assignment in Japan as head of our joint venture with Hitachi and will be available to provide his insight into any questions the subcommittee may have on international ceramic activity, particularly the status of things in Japan.

[Slides shown.]

Statement For The Record Of

JONATHAN W. HINTON
Vice President and General Manager
Structural Ceramics Division
Standard Oil Engineered Materials Company

Representing
The United States Advanced Ceramics Association

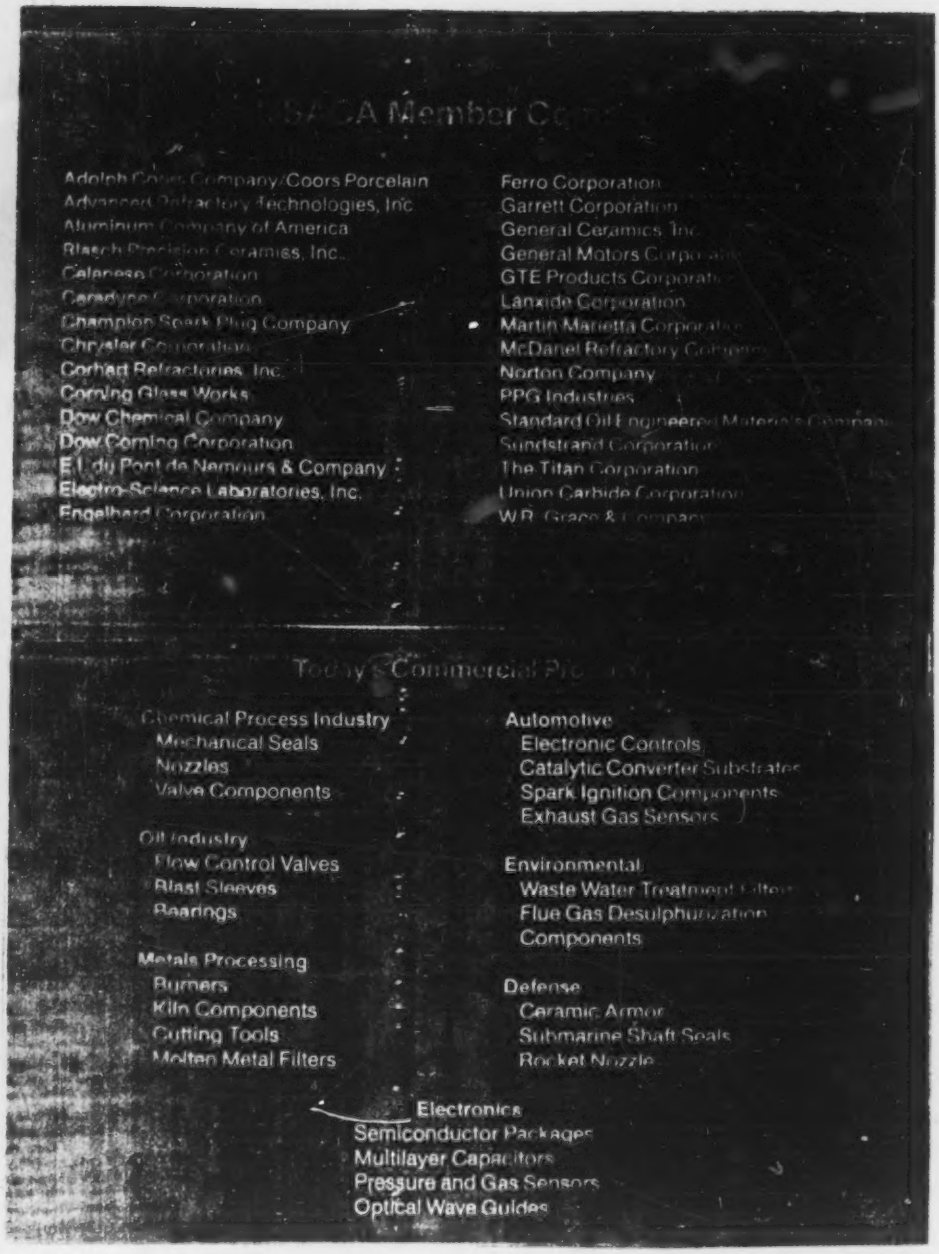
Before The

House Science and Technology Committee
Subcommittee on Transportation, Aviation, and Materials

September 17, 1986

USACA

Promote the commercialization of the United States advanced ceramic industry.


CA Member Co
Adolph Coors Company/Coors Porcelain
Advanced Refractory Technologies, Inc
Aluminum Company of America
Blasch Precision Ceramics, Inc.
Caterpillar Corporation
Ceradyne Corporation
Champion Spark Plug Company
Chrysler Corporation
Corhart Refractories, Inc.
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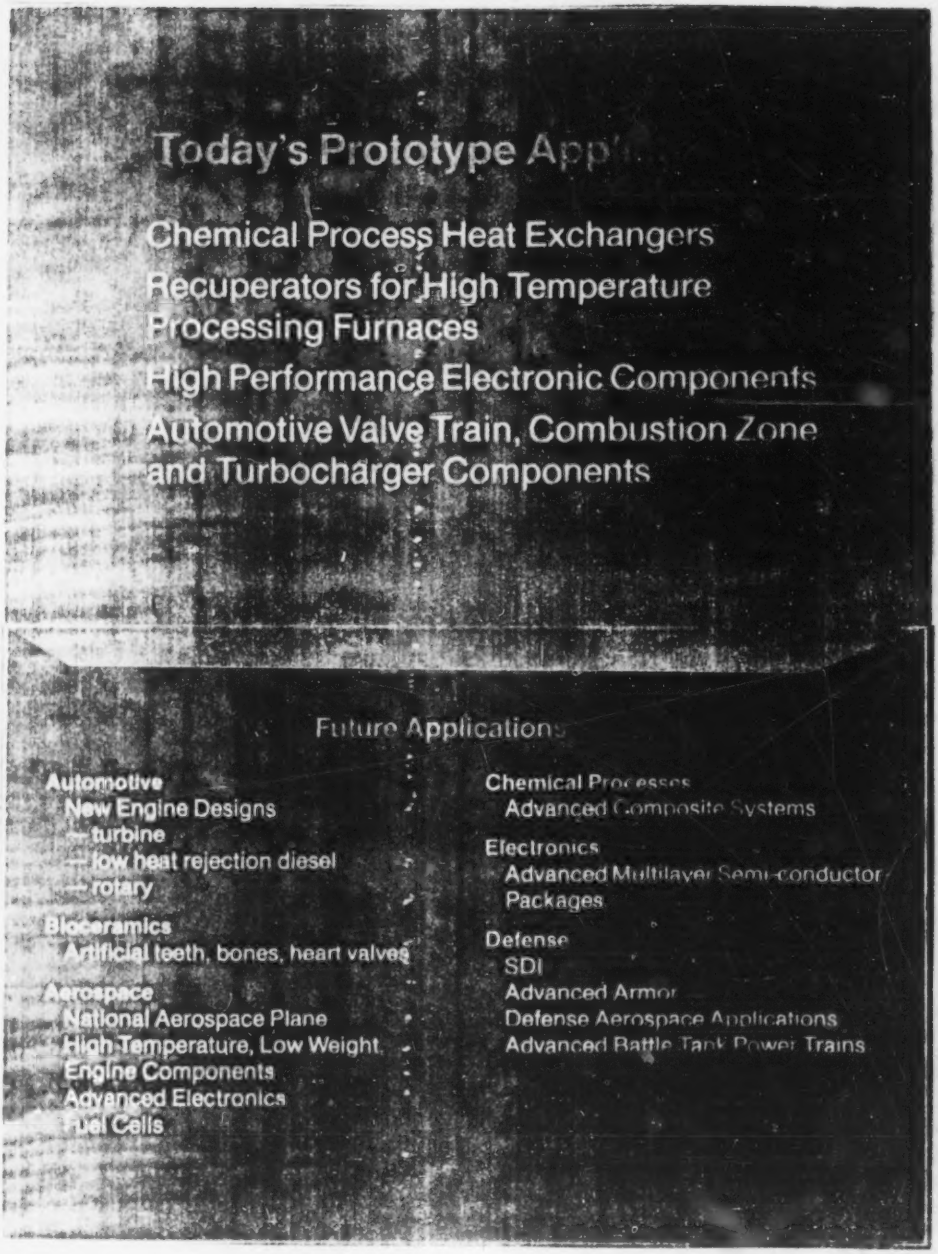
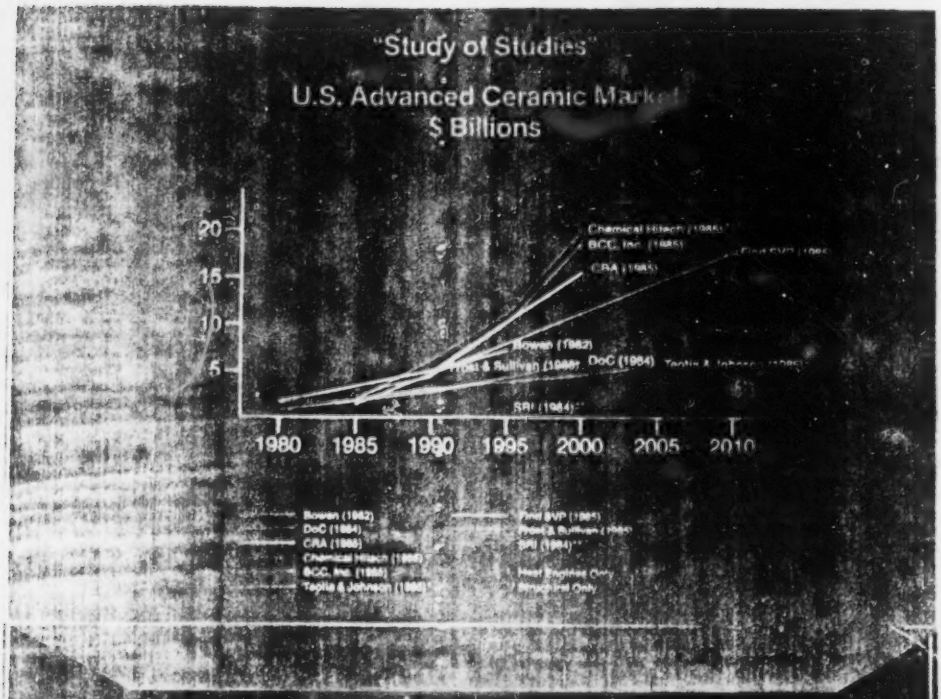
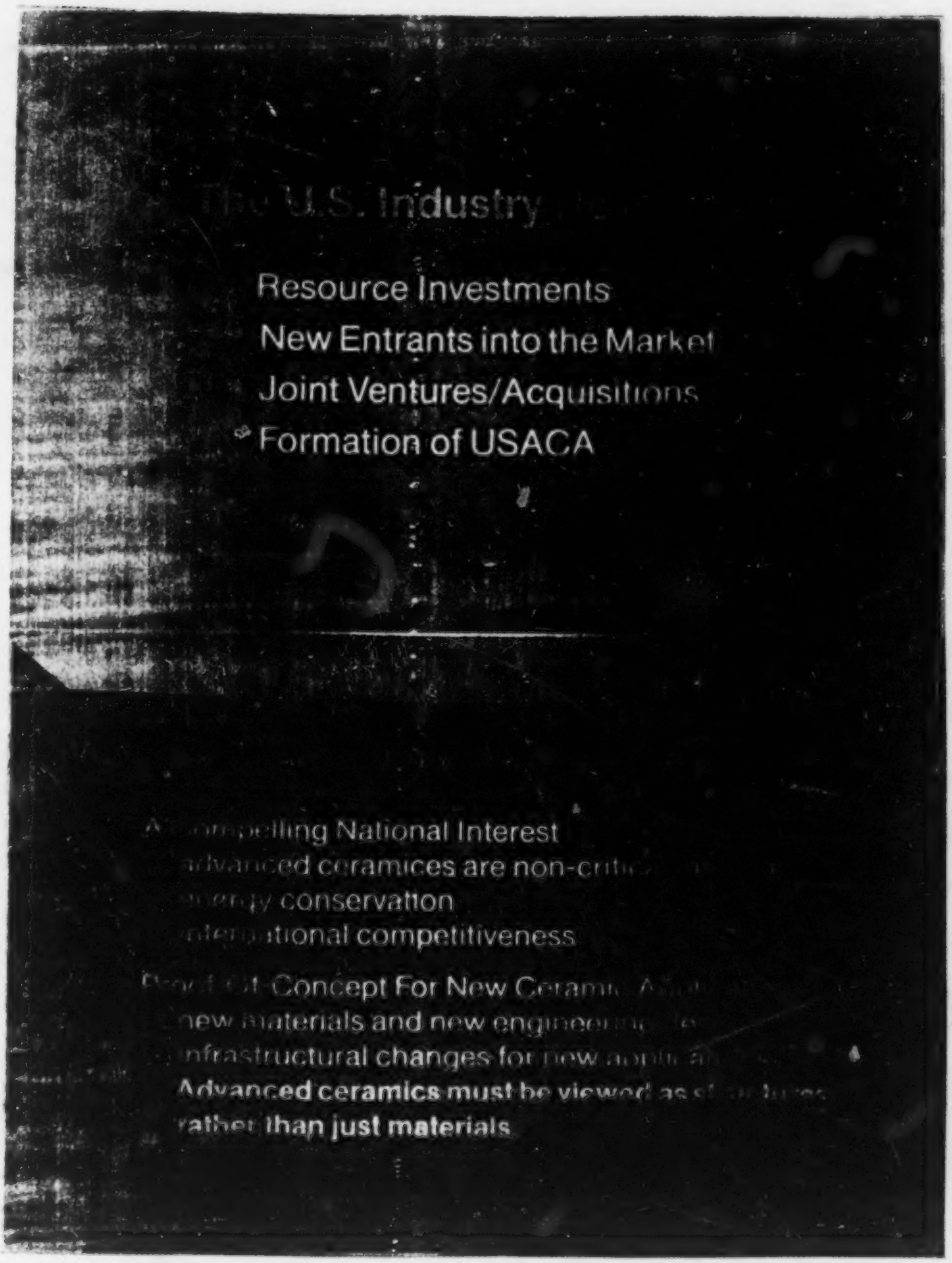
W.R. Grace & Company
Today's Commercial Pro
Chemical Process Industry
Mechanical Seals
Nozzles
Valve Components
Oil Industry
Flow Control Valves
Blast Sleeves
Bearings
Metals Processing
Burners
Kiln Components
Cutting Tools
Molten Metal Filters
Automotive
Electronic Controls
Catalytic Converter Substrates
Spark Ignition Components
Exhaust Gas Sensors
Environmental
Waste Water Treatment Filters
Flue Gas Desulphurization Components
Defense
Ceramic Armor
Submarine Shaft Seals
Rocket Nozzle
Electronics
Semiconductor Packages
Multilayer Capacitors
Pressure and Gas Sensors
Optical Wave Guides


Today's Prototype Appl
Chemical Process Heat Exchangers
Recuperators for High Temperature Processing Furnaces
High Performance Electronic Components
Automotive Valve Train, Combustion Zone and Turbocharger Components
Future Applications
Automotive
New Engine Designs
— turbine
— low heat rejection diesel
— rotary
Bioceramics
Artificial teeth, bones, heart valves
Aerospace
National Aerospace Plane
High Temperature, Low Weight Engine Components
Advanced Electronics
Fuel Cells
Chemical Processes
Advanced Composite Systems
Electronics
Advanced Multilayer Semi-conductor Packages
Defense
SDI
Advanced Armor
Defense Aerospace Applications
Advanced Battle Tank Power Trains



International Activ

Japan
West Germany
Sweden
United Kingdom
France/Italy
Iron Curtain Countries


The U.S. Industry
Resource Investments
New Entrants into the Market
Joint Ventures/Acquisitions
Formation of USACA
Advanced ceramics must be viewed as
rather than just materials

Advis[illegible]ent and other key gove[illegible]
regar[illegible]portance of advanced
Ass[illegible]ulation of Executive B[illegible]
Identify [illegible]eeded research.
Identify and inform U.S. industry of adva[illegible]
activities in Iron Curtain countries.
Identify overlap and unnecessary duplicat[illegible]
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Consult with the advanced ceramics indus[illegible]

Need For Additio[illegible]
A[illegible]vanced Ceramic Federal Go[illegible]

The past and present Federal government R & D expenditures for Advanced Ceramics have been successful.

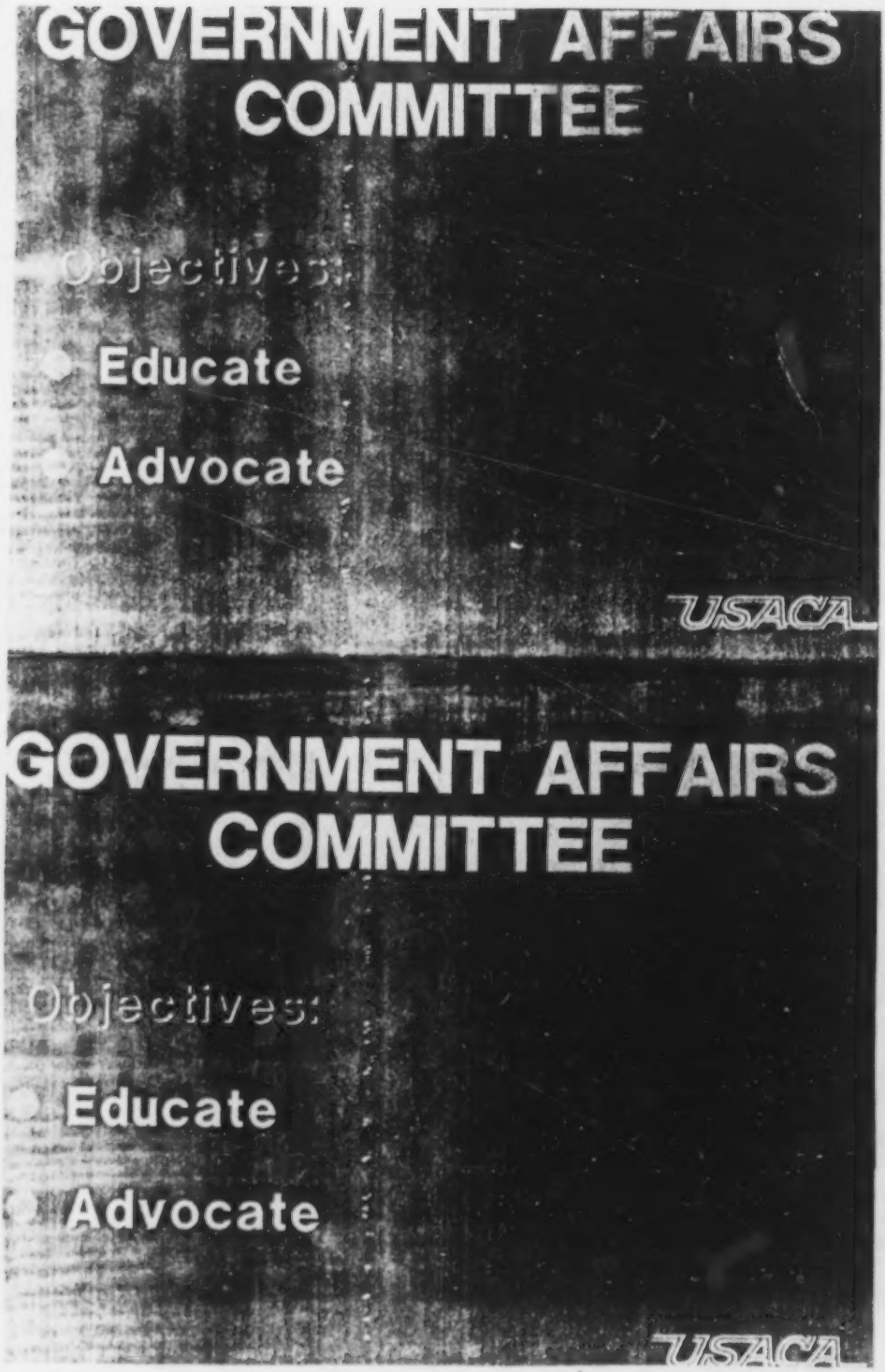
The U.S. is at the threshold of developing a healthy and stable advanced ceramic industry able to compete in worldwide markets.

There still remains several key areas where Federal Government R &D is needed.

— Basic Research
— New Materials & Structures
— New Systems

Advanced ceramics offer tremendous advantages over other materials in certain applications and their future development is strategically critical to the advanced material needs of the U.S.

Establish "Proof-of-Concept" for advanced applications


GOVERNMENT AFFAIRS
COMMITTEE
Objectives:
Educate
Advocate
USACA
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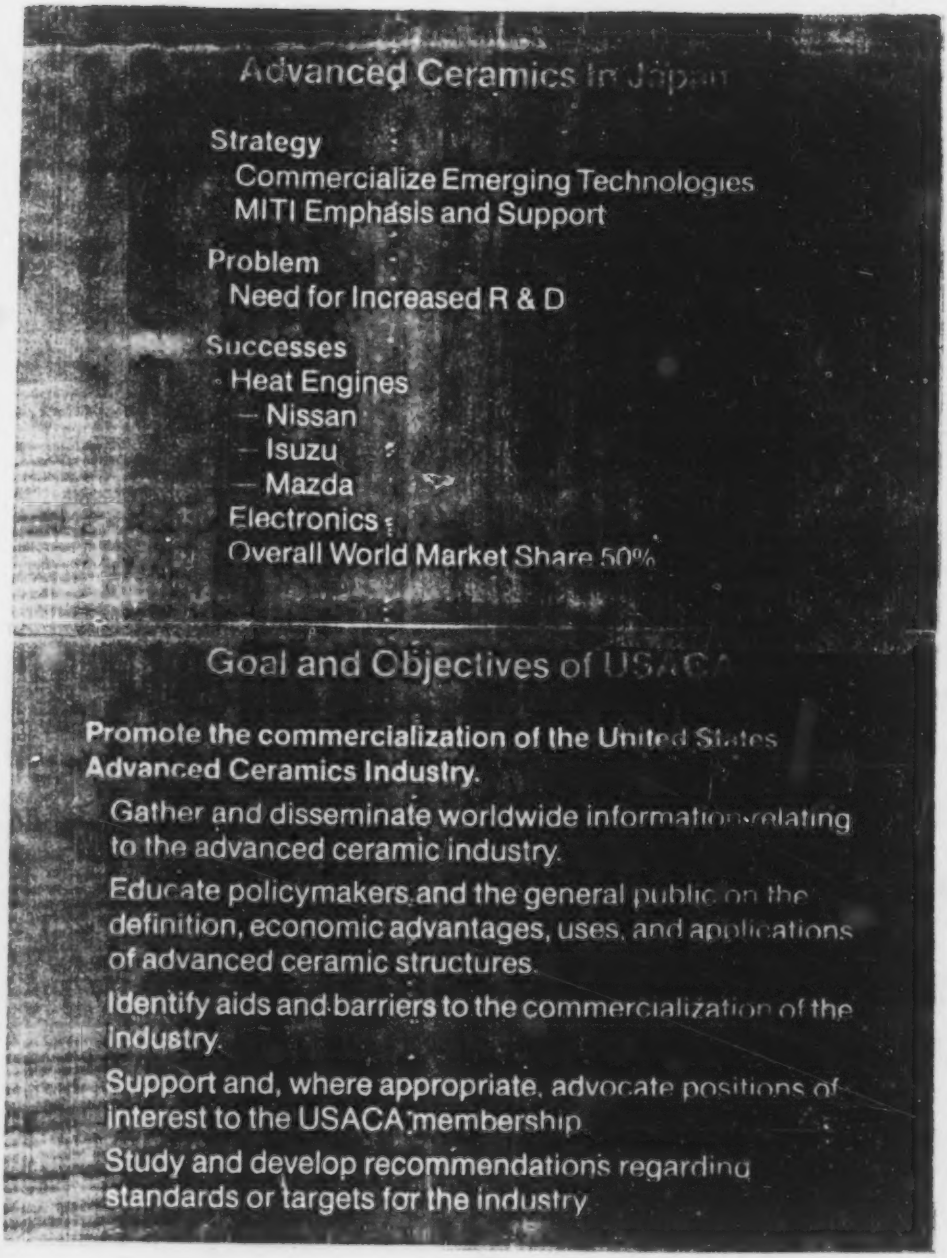
Advanced Ceramics in Japan
Strategy
Commercialize Emerging Technologies
MITI Emphasis and Support
Problem
Need for Increased R & D
Successes
Heat Engines
— Nissan
— Isuzu
— Mazda
Electronics
Overall World Market Share 50%
Goal and Objectives of USACA
Promote the commercialization of the United States Advanced Ceramics Industry.
Gather and disseminate worldwide information relating to the advanced ceramic industry.
Educate policymakers and the general public on the definition, economic advantages, uses, and applications of advanced ceramic structures.
Identify aids and barriers to the commercialization of the industry.
Support and, where appropriate, advocate positions of interest to the USACA membership
Study and develop recommendations regarding standards or targets for the industry

Dr. HINTON. I'd like to start off with a few words about USACA. USACA is the national trade association currently representing 30 companies with an interest in the emerging field of advanced ceramics. I think you can see it's quite a cross section of American industry represented there.

Formed on July 10, 1985, the organization is dedicated to promote free market approaches to the advancement and commercialization of advanced ceramic products and in other ways better serve the interests of the U.S. advanced ceramic community.

Ceramics include a wide range of inorganic, nonmetallic materials processed or consolidated at high temperatures. You are routinely familiar, I'm sure, with the more traditional ceramic products, such as dinnerware, tile, electric porcelain, plumbing fixtures, and the like.

Technological advances have now provided an emerging class of improved materials known as advanced ceramics. The potential advantages of these new ceramics are extremely important to the future material needs of the United States.

Even though this emerging U.S. advanced ceramic industry is small and still highly research-oriented, several commercial markets have been developed. They include applications in the chemical process industry, oil, metals processing, electronics, automotive, environmental, and defense. I think it's interesting to note that many of these are the same critical industries we heard Dr. Moore reference earlier this morning.

Prototype applications moving toward commercialization include areas shown in the next slide. The real excitement, however, in the future for advanced ceramics will be in applications which need improved strength, hardness, thermal, chemical, and electrical properties where traditional materials simply are unable to do the required job.

We see research leading to the use of advanced ceramics in several major industries. These engineered ceramics will be performance optimized for applications, as you can see here, in automotive, bio-ceramics, aerospace, chemical process, electronics, and defense—again, many of the same industries, but now we're looking at future advanced products.

In the case of both passenger cars and trucks, the use of ceramics in engines can improve fuel efficiency and thereby enhance the worldwide competitive position of the United States in motor vehicle markets. In fact, given the current activity in Japan, it appears that we must achieve major gains in the technology and production of advanced ceramics just to maintain the competitive status quo.

There is an intense international competition to develop and commercialize advanced ceramic technology. A recent Canadian Government study cites a potential global market of $30 billion by the year 2010 plus an additional $60 billion in productivity and energy cost savings.

Here are shown some of the many studies of the United States advanced ceramic market through 2010. I think you can see there is some diversity in the forecast, but in any case the markets appear to be substantial and certainly worth penetrating.

The United States, Japan, West Germany, Sweden, France, Italy, Iron Curtain countries are all involved to varying degrees in ad-

vanced ceramic research and market development. There is considerable background on each of these countries in my written statement. I would only highlight here that in Japan the long-term strategy has been to target early these high potential, high risk opportunities. MITI, the Ministry of International Trade and Industry, is very successful at doing that. They recognize, of course, the potential to alleviate many of Japan's energy problems and to further provide material support to other emerging industries and thereby maintain export dominance. Through this, we estimate the current share of the advanced ceramic market for Japan as about 50 percent.

The emerging U.S. advanced ceramics industry represents a significant resource commitment. USACA member companies are spending many millions of dollars for research and development and for production facilities. New companies have entered the business, others have expanded their operations, developed joint ventures, or made key acquisitions in order to become strategically placed in the emerging advanced ceramic industry. A real sense of urgency is becoming evident across the industry. These investments are just now beginning to yield results. New and improved materials are being developed with mechanical and electrical properties superior to earlier ceramics. New products are being offered to the market in a wide variety of applications.

Another response by industry has been the founding of USACA. Barely a year old, USACA came about when a number of the leading companies in advanced ceramics recognized that the challenges facing the industry were simply too great for individual companies to conquer alone. USACA's goal, objectives, and activities to date are attached to my written statement.

USACA stands for a free market approach to international competitiveness and the commercialization of the industry, but the industry is small relative to the huge opportunities before us. Significant continuing support from the Federal Government in the development of a coherent U.S. critical materials policy is essential for the U.S. industry to succeed.

Federal Government involvement in ceramic R&D is a compelling national interest. The need to show proof of concept for new ceramic applications is essential. A real sense of urgency is certainly appropriate.

As you can see, advanced ceramics are made from readily available raw materials and therefore have far fewer strategic material problems than metal-based super-alloys. Significant energy savings result from their use in high-temperature applications. The use of advanced ceramics by U.S. industry can lead to improvements in productivity and cost-effectiveness of many industrial processes, thereby strengthening U.S. international competitiveness.

Proof of concept is essential to provide sufficient market pull for new applications, and I believe this was discussed somewhat fully earlier, and I certainly agree with the comments that were made both by the chairman and by my learned colleague.

A multibillion-dollar potential exists for new advanced ceramic applications, but completely new materials and new engineering designs are required. The industry is in an embryonic stage, and a long-term outlook is required which encompasses a total systems

approach to design and cost. Advanced ceramics must be viewed as structures rather than just materials.

The National Critical Materials Council has an important role to play with regard to advanced ceramics. Based on the responsibilities of the Council as set forth in the 1984 act, we believe the Council could do the following for advanced ceramic R&D within the Federal Government: First, advise the President and other key Government officials regarding the importance of advanced ceramics; assist in the formulation of executive branch policies; identify needed areas of advanced ceramic research; identify and inform U.S. industry of advanced ceramic activities behind the Iron Curtain; identify overlap and unnecessary duplication concerning advanced ceramic R&D; maintain a centralized database of ongoing activities; and, finally, consult with the advanced ceramic industry itself on matters of material importance.

There remains a need for continuing Federal Government support of advanced ceramic R&D. I would like to point out that the past and present Federal Government R&D expenditures for advanced ceramics have been successful. They brought us to the point where we are at the threshold of developing a healthy and stable advanced ceramic industry able to compete in world-wide markets. Those markets that we see, of course, are twofold; they are electronic, and they are structural.

I would like to remind the subcommittee that we have lost a large part of the electronic components business to Japan, however, due to their large investments in ceramic R&D which have resulted in lower cost manufacturing technologies. For structural ceramics, however, there is no clear indication yet that either Japan, Europe, or the United States have a general technological lead. Without significant R&D efforts, however, the United States will surely fall behind.

Japanese ceramic R&D appears to be aimed at process technology and material composition improvements. This approach, when coupled with targeted application development, enables the Japanese to commercialize new products quickly, gain production experience, and reduce market prices. They certainly have the sense of urgency.

Several key areas remain where Federal Government advanced ceramic R&D is needed, as shown in this slide, certainly in the basic R&D area, in the development of systems and structures, and in the identification and development of new systems, such as engines, designed to take full advantage of the attributes of ceramics.

Advanced ceramics do offer tremendous advantages over other materials in certain applications. Their future development is critical to the advanced material needs of the United States. The U.S. Advanced Ceramics Association strongly encourages Congress to continue to fund Federal Government R&D for advanced ceramics. To do less could severely jeopardize the proof of concept of advanced ceramic materials in several critical applications and thereby delay commercialization of vitally needed advanced ceramic materials.

In conclusion then, we would advocate that as the Congress has set forth in the National Critical Materials Act of 1984, there is truly a need to identify and coordinate all Federal Government ad-

vanced ceramic R&D activity. Furthermore, it is essential that the President and other key Government officials be advised of the tremendous potential for advanced ceramics in the United States. The newly created National Critical Materials Council would appear to be an appropriate forum for these endeavors.

USACA member companies would like to offer their assistance in helping to ensure that the coordinated and effective Federal Government advanced ceramic R&D program continues in the ensuing years.

Dr. Coppola and I would now be glad to answer any questions that the subcommittee may have.

[The statement of Dr. Hinton follows:]

USACA

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ADVANCED CERAMICS ASSOCIATION
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STATEMENT FOR THE RECORD OF

JONATHAN W. HINTON
Vice President and General Manager
Structural Ceramics Division
Standard Oil Engineered Materials Company

REPRESENTING

THE U. S. ADVANCED CERAMICS ASSOCIATION

BEFORE THE
House Science and Technology Committee
Subcommittee on Transportation, Aviation, and Materials

September 17, 1986

Mr. Chairman and Members of the Subcommittee, my name is Jonathan Hinton. I am Vice President and General Manager, Structural Ceramic Division, Standard Oil Engineered Materials Company. This Statement is being submitted for the Record in my capacity as Chairman of the Government Affairs Committee of the United States Advanced Ceramics Association, known as USACA. We are pleased to have this opportunity to discuss USACA's views on implementation of the Critical Materials Act of 1984 by the National Critical Materials Council. My testimony will focus on the Federal Program Plan as it relates to advanced ceramics and the importance of advanced ceramic research and development to the United States.

Joining me today, is Dr. John A. Coppola, Manager of Advanced Programs for Standard Oil Engineered Materials Company. He has recently returned from a three-year assignment in Japan, and will be available to provide his insight into any questions the Subcommittee may have on international ceramic activities, particularly the status of advanced ceramics in Japan.

USACA

USACA is a national trade association currently representing 30 companies with an interest in the emerging field of advanced ceramics. A copy of the USACA member companies is attached to my statement for information (Appendix A). Formed in October of 1985, the organization is dedicated to promote free market approaches to the advancement and commercialization of advanced ceramic products and in other ways better serve the interests of the United States advanced ceramics industry. USACA's goals, objectives, and activities to date are shown in Appendix B.

WHAT ARE ADVANCED CERAMICS

"Ceramics" include a wide range of inorganic nonmetallic materials processed or consolidated at high temperatures. People are familiar with the more traditional ceramic products such as dinnerware, tile, electrical porcelain, plumbing fixtures and the like (represented by SIC Codes 3251,3261,3263,etc.). Technological advances have provided a new, improved class of materials known as "advanced ceramics." The potential advantages of these new ceramics are widespread and are extremely important to the future material and national security needs of the United States. To date, no specific SIC Codes exist for most of these applications.

The development of high-temperature advanced ceramic materials began in the 1960s, and was largely motivated by the possibility of substantially improving the efficiency of gas turbines by raising their maximum operating temperatures. The material characteristics offered by the ceramics of that era showed much promise. In the 1970s, several major U.S. Department of Defense research initiatives explored and advanced the experimental fabrication and utilization of ceramics in gas turbines. Federal Government sponsored research has continued into the 1980s with the U.S. Department of Energy Advanced Gas Turbine Programs and the Ceramic Technology R & D Projects under the Advanced Materials Development Program. Similar efforts have been undertaken in other countries, notably in West Germany and in Japan. The Federal Government ceramic R & D work has been instrumental in contributing to the technology base for subsequent work in the United States.

It has taken many years and considerable resources to achieve today's process capabilities and variety of ceramic material systems, involving silicon carbide, silicon nitride, zirconia, and toughened alumina, with promise of usable strengths in some applications up to 1200C degrees or higher.

The recently released report by the Office of Technology Assessment New Structural Materials Technologies clearly states the situation with respect to advanced ceramics: large opportunities with high risks, aggressive international competition, current high costs and a lack of rapid, reliable manufacturing methods. Particularly, insightful in this report was the view of advanced ceramics as structures not just as materials with an emphasis on design and costs in a systems orientation[1].

ADVANCED CERAMIC APPLICATIONS

I. Today's Commercial Products

Even though the U.S. advanced ceramics industry is small and still highly research oriented, several commercial markets have been developed. These can be summarized as follows:

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1 OTA draft, New Structural Materials Technologies: Opportunites For The Use Of Advanced Ceramics And Composites, April 25, 1986, See Pages 142-144.

- Chemical Process Industry
  - mechanical seals
  - nozzles
  - valve components

- Oil Industry
  - flow control valves
  - blast sleeves
  - bearings

- Metals Processing
  - burners
  - kiln components
  - cutting tools
  - molten metal filters

- Aerospace
  - missle radomes
  - space shuttle tile

- Electronics
  - semi-conductor packages
  - multi-layer capacitors
  - pressure and gas sensors
  - optical wave guides
  - ceramic magnets

- Automotive
  - electronic controls
  - catalytic converter substrates
  - spark ignition components
  - exhaust gas sensors

- Environmental
  - waste water treatment filters
  - fluegas desulfurization components

- o Defense
  - ceramic armor
  - submarine shaft seals
  - rocket nozzles

- o Bio-ceramics
  - bone or joint replacements
  - dental restoration

2. Today's Prototype Applications

Emerging/prototype applications include:

- o Chemical process heat exchangers
- o Recuperators for high temperature processing furnaces
- o Higher performance electronic components
- o Automotive valve train, combustion zone and turbocharger components

Future Applications

The real excitement and future for advanced ceramics lies in applications which need improved strength, hardness, thermal, chemical, and electrical properties. Ceramics are essential in these applications because traditional materials are unable to do the required job. We see research leading to the use of advanced ceramics in several major industries. These ceramics will be engineered to provide needed properties for the following applications:

- o Automotive
  - new engine designs such as turbine, low heat rejection (LHR) diesel, and advanced rotary

- o Bio-ceramics
  - artificial teeth, bones, heart valves

- o Aerospace
  - national aerospace plane
  - high temperature, low weight components for engines
  - advanced electronics
  - fuel cells and batteries
- o Chemical Processes
  - advanced composite systems
- o Electronics
  - advanced multi-layer semi-conductor packages
- o Defense
  - SDI (optical/heat transfer properties)
  - improved armor for high threat levels
  - defense aerospace applications
  - advanced battle tank power trains

In the case of motor vehicles (both passenger cars and trucks) the use of advanced ceramics in engines can improve fuel efficiency and help to maintain or improve the worldwide competitive position of the U. S. in motor vehicles markets. An earlier study by Argonne National Laboratory (the study is now in the process of being updated by Argonne working through USACA), showed the macro-economic effects of U. S. or Japanese dominance in structural advanced ceramic technology for heat engines[2]. Though a more realistic view of the likely penetration of ceramics will reduce the anticipated economic impact, the competitiveness issue remains. In fact, it appears that the U. S. must achieve major gains in technological and production expertise in advanced ceramics just to maintain the competitive status quo, given the current activities in Japan.

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2 Teotia, Arvind P.S. and Johnson, Larry R., "Macroeconomic Effects of U.S. or Japanese Dominance in Structural Ceramic Technology for Heat Engines", American Ceramic Society Bulletin, (September 1985), pp. 1232-36.

INTERNATIONAL ACTIVITIES IN ADVANCED CERAMICS

There is intense international competition to develop and commercialize advanced ceramics technology. A potential global market of $30 billion by the year 2010 and an additional $60 billion in productivity and energy cost savings provide a strong incentive to be a world leader in this emerging field.[3] The United States, Japan, West Germany, Sweden, France and Italy are all involved to varying degrees in research and market development. Japan is in the forefront in terms of their manpower commitment, with an estimated 4,000 scientists, engineers and technicians devoted to advanced ceramics. The United States employs up to 1,000 scientists and engineers specifically involved in ceramics R & D with an additional 1,000 to 2,000 peripherally involved. In Appendix C, a country by country discussion of international activities in advanced ceramics is provided.

THE U. S. INDUSTRY RESPONSE

The emerging U. S. advanced ceramics industry has invested significant resources in research and development, and production facilities. USACA member companies are spending many millions of dollars for research and development and facilities. New companies have entered the business, others have expanded their operations, developed joint ventures or made key acquisitions in order to become strategically placed in the emerging advanced ceramic industry.

These investments are just beginning to yield results. New and improved materials are being developed with mechanical and electrical properties superior to earlier ceramics. New products are being offered to the market in a wide variety of applications.

Another response by industry was the founding of USACA. Barely a year old, USACA came about when a number of the leading companies in the advanced ceramics industry recognized that the challenges facing the industry were too great for individual companies to conquer alone.

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3 Government of Canada, Office of Industrial Innovation, Department of Regional Industrial Expansion. Advanced Ceramics: Technology Situation Report (Sept. 1985) Draft.

USACA is in the process of summarizing the research and development expenditures for advanced ceramics of its member companies, including the amounts of Federal Government funding. Unfortunately, the task is not yet complete, but the results will be made available to this Subcommittee later this year.

As stated earlier, USACA stands for free-market approaches to the commercialization of the advanced ceramic industry and international competitiveness. However, the industry is small relative to potential opportunities. Significant continuing research and development support from the Federal Government and implementation of a coherent critical materials policy is essential if the U. S. is to achieve the potential offered by advanced ceramics.

U. S. FEDERAL GOVERNMENT AGENCY SUPPORT OF ADVANCED CERAMICS R&D

Advanced ceramic materials offer enormous potential to the U.S. in the automotive, bio-ceramics, aerospace, defense, electronic and chemical process industries. However, the timing and need for technological breakthroughs is critical. Research on advanced ceramics has in the past been supported by several agencies of the Federal Government, including:

- o Department of Energy
- o Department of Commerce/National Bureau of Standards
- o Department of Defense
  - -DARPA
  - -Army
  - -Navy
  - -Air Force
- o NASA
- o National Science Foundation

R & D efforts have focused on basic research in the fundamental science of ceramics, development of improved ceramic process technology, and development of new engineering designs to take into account the characteristics of ceramics. Continued federal involvement will help to establish a healthy and stable advanced ceramic industry in the United States that will enable the U. S. to be a world leader in the emerging worldwide ceramic market.

A March 1984 Department of Commerce report, which assessed the competitiveness of the U.S. advanced ceramic industry, noted that there are a number of available options to strengthen the competitive position of the industry in the United States. Those suggested options include[4]:

- "Increasing the amount of Federal Research and Development expenditures related to advanced engineering ceramics.
- Increasing the amount of Federal R&D aimed at military and space applications of advanced ceramics and improving the technology transfer function to commercial applications.
- Increasing Federal incentives directed toward increasing private industry R&D on advanced engineering ceramics.
- Allowing antitrust exemptions for cooperative industrial R&D to develop major advanced engineering ceramic applications and promote the Research and Development Limited Partnership (RDLP) concept for this purpose.
- Improving U.S. capacity to obtain and disseminate foreign scientific and technical information (STI).
- Increasing educational opportunities and incentives for product design and manufacturing of advanced engineering ceramics."

The report also suggested several options whereby the Federal Government could create or improve the market for advanced ceramics:[5]

- "Increase Federal procurement of advanced engineering ceramics for military, space, and other applications.
- Use Federal regulatory policy to increase the market for advanced engineering ceramics.
- Provide Federal risk or liability insurance for advanced engineering ceramics producers and/or users in case of catastrophic failure.

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4 U. S. Department of Commerce, A Competitive Assessment of the U. S. Advanced Ceramic Industry, (March 1984), pp. xvi-xvii.

5 Ibid., p. xvii

- o Review the Standard Industrial Classification codes to separately identify advanced ceramic production, use, and trade. This would facilitate assessing developments within the industry.

- o Encourage the various standards setting associations to develop, in concert with the National Bureau of Standards, preliminary reliability standards for advanced ceramics. As more knowledge is available from ongoing research programs, the standards should be revised accordingly."

The National Science Foundation identified that $44.2 billion was spent in FY 1984 for Federal Government R & D expenditures. However, the major structural ceramics R & D programs conducted by DOE, DOC, DOD, NASA, National Bureau of Standards and National Academy of Sciences account for only $50.8 million of this $44.2 billion total according to DOE documents.

Since FY 1984, total R & D funding in the Federal Government has increased to an estimated $58.3 billion in 1986[6], but the Administration's FY87 proposed funding for structural ceramics R & D was decreased to $45.7 million in 1986[7]. USACA applauds the action of this Subcommittee in its support of Federal Government funding for both the Advanced Gas Turbine and Ceramic Technology programs.

WHY FEDERAL GOVERNMENT INVOLVEMENT IS NEEDED

Federal Government involvement in Advanced Ceramic R&D is needed for two major reasons: a compelling national interest, and the need to show "proof-of-concept" for new ceramic applications. Thereafter, the advanced ceramics industry can move forward to commercialize a given product application. This is further explained below:

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6 "U.S./R&D", Government Data Publications, (January, 1986), p. 8972-74.

7 U. S. Department of Energy, Structural Ceramic Technology, Federal Government Funded R & D (February 1986).

A compelling national interest

There exists a national interest in further developing advanced ceramics for three specific reasons:

- Strategic Material Implications: Advanced ceramics are composed from readily available materials and therefore have far fewer strategic material problems than metal-based superalloys.

- Energy: Consumption of energy in the production of advanced ceramics is considerably less than the savings that result from their use in high temperature applications.

- International competitiveness: An opportunity exists for U. S. dominance of a new and growing market. Also, the use of advanced ceramics by U. S. industry can lead to improvements in the productivity and cost-effectiveness of many industrial processes.

Proof-of-concept for new ceramic applications

The Federal Government's appropriate role for advanced ceramics should be both to support basic research to develop the technology and to provide proof-of-concept test, evaluation, and demonstration in applications that have future promise. The DOE Advanced Gas Turbine (AGT) Program and the complementary Ceramic Technology for Advanced Heat Engines Program are excellent examples of such programs that the government should continue to fund. In addition, programs should be continued in other advanced ceramic applications, such as the Low Heat Rejection (LHR) diesel and heat exchangers.

National security and energy conservation goals can be enhanced through the development of weapons systems and energy efficient equipment that utilize advanced ceramics in their design, providing higher temperature capability, longer operating life, and greater operating efficiencies than current designs. Federal agencies, by demonstrating the application of advanced ceramics, will provide items for a fledgling industry to develop and manufacture, thus providing the necessary market pull. We strongly endorse government funding of advanced ceramic technology development to provide proof-of-concept to then allow the industry to commercialize the product.

Government programs should not compete with those of industry or duplicate existing technology.

The proof-of-concept for new advanced ceramic applications is essential for the reasons explained below:

- There exists a multi-billion dollar market potential for new advanced ceramics applications.

- Completely new materials and new engineering designs are required.

- Infrastructural changes would result from new types of engines for automobiles and other applications.

- Since the industry is in an embryonic stage, a long-term outlook is required which encompasses a total systems approach to design and costs. Advanced ceramics have to be viewed as structures rather than just materials.

In addition to the individual activities by USACA members, efforts are also underway to establish an interdisciplinary ceramics center to accelerate the development of advanced processing techniques. The proposed center, known as the Ceramic Advanced Manufacturing Development & Engineering Center (CAMDEC) is planned as a joint effort by the advanced ceramic industry, a government laboratory such as The Oak Ridge National Laboratory, and a university affiliation. It's goal will be to enhance the international competitiveness of the U. S. ceramic industry, to conduct generic manufacturing engineering development on the processing of advanced ceramic materials, prepare students for careers in ceramic engineering, and establish a long-term partnership among industry, academia, and government.

THE ROLE OF THE NATIONAL CRITICAL MATERIALS COUNCIL

Based on the responsibilities of the Council, as set forth in the National Critical Materials Act of 1984, we believe the Council could do the following for advanced ceramic R&D within the Federal Government:

o Advise the President and other key government officials regarding the importance of advanced ceramics for the national interest in terms of job creation and materials technological advancement.

- Assist in the formulation of Executive Branch policies for advanced ceramics.

- Identify for the President and the Executive Branch Agencies needed areas of advanced ceramic research.

- Identify and inform U. S. industry of advanced ceramic R & D activities in the Iron Curtain countries.

- Identify overlap and unnecessary duplication in the Executive Branch concerning advanced ceramic R & D activities.

- Maintain a centralized database of ongoing advanced ceramics R&D activities within the Executive Branch.

- Consult with the advanced ceramic industry on matters related to materials R&D, material applications, and other related matters.

The concern that unnecessary duplication of advanced ceramic R & D within the Federal Government be eliminated, and that coordination of various agency initiatives and programs occur to prevent the misallocation of scarce taxpayer dollars, has been reduced by the initiative of the Department of Energy. We understand that interagency coordination meetings are held on a bi-monthly basis under DOE/NASA leadership and an Interagency Coordinating Committee on Ceramics holds annual meetings to avoid overlap and duplication within the Federal Government on advanced ceramic R & D. Furthermore, DOE has established an elementary database of ongoing unclassified advanced ceramic R & D activities within the Executive Branch Agencies. We believe the newly-created National Critical Materials Council could play an additional role in these endeavors, along with the other important areas delineated above.

NEED FOR ADDITIONAL ADVANCED CERAMIC FEDERAL GOVERNMENT R & D

1. The past and present Federal Government R & D expenditures for advanced ceramics have been successful.

DOE sponsored ceramic technology development and advanced heat engine programs and other Federal Government advanced ceramic technology programs have

made substantial gains toward their goals and have been successful in precipitating increased involvement and investment by U.S industry. Material properties of advanced ceramics have improved and net shape components with better performance are now available to engine builders for evaluation. This funding has greatly broadened the scope of design, fabrication and testing. Continuing R & D programs at current and increased funding levels for FY 87 and beyond are needed to carry forward the accomplishments of the existing programs. This will help to achieve the goal of developing advanced ceramic technology that will allow the U. S. industry to make future commercialization decisions.

2. The U.S. is at the threshold of developing a healthy and stable advanced ceramic industry able to compete in worldwide markets.

The advanced ceramics industry encompasses two principal businesses — electronic components and structural components. The United States has lost a large part of the electronic ceramic component business to Japan due to their large investments in ceramic R & D, resulting in lower costs of manufacturing. At present, however, there is no clear indication that either Japan, Europe, or the United States has a technological lead in advanced ceramics. Without significant R & D efforts, the U.S. will surely fall behind. Japanese advanced ceramic R & D appears to be aimed at process technology and materials composition improvements. This approach enables the Japanese to commercialize new products more quickly, gain production experience and reduce market prices. Therefore, continued U.S. expenditures for R & D for advanced ceramics are a critical factor in helping to ensure that the U.S. continues to be a key player in advanced ceramics technology development as this industry becomes more commercialized.

3. There still remains several key areas where Federal Government advanced ceramic R & D is needed.

We have identified three major areas where additional Federal Government advanced ceramic R & D is needed:

- o Basic research in the fundamental science of ceramics.
- o Development of dependable ceramic materials and structures required for advanced systems[8].

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8 Actions in this area are now underway in the Department of Energy's Ceramic Technology in Advanced Heat Engines (CTAHE)

- powder synthesis
- powder processing
- net shape fabrication and sintering
- final machining and joining

o Development of new systems designed to take advantage of the attributes of advanced ceramics (i.e. engines).

4. Advanced ceramics offer tremendous advantages over other materials in certain applications and their future development is critical to the advanced material needs of the U.S.

The advantages of advanced ceramics over other materials can be summarized as follows:

o Improved hardness, wear resistance, chemical durability, optical, and high temperature capability versus metals.

o Made from elements abundant in the U.S. and therefore not dependent upon foreign sourced raw materials.

o Once processing is adequately developed, costs of manufacture are low as compared to other comparable materials.

o Ceramic components are generally lower in weight than metal equivalents.

o Energy saving occurs in many applications, thereby lessening dependence on foreign energy suppliers.

o Ceramics offer improved durability in most applications.

o The opportunity for the U.S. to dominate a potentially very large worldwide market in the late 1990's.

Overall, advanced ceramics have properties which allow them to be used in demanding environments far beyond the capabilities of metals, plastics, or conventional ceramics.

CONCLUSION

As Congress has set forth in the National Critical Materials Act of 1984, there is a need to identify and coordinate all Federal Government critical material activities. We believe that advanced ceramics R & D activity falls within this purview.

It is essential that the President and other key government officials be advised of the tremendous potential of advanced ceramics for the United States. The newly created National Critical Materials Council appears to be an appropriate forum for these endeavors.

The U.S. Advanced Ceramic Association strongly encourages Congress to continue to fund Federal Government R&D for advanced ceramics. To do less could severely jeopardize the "proof-of-concept" of advanced ceramic materials in several critical applications and, thereby, delay commercialization of vitally needed advanced ceramic materials. USACA member companies offer their assistance in helping to ensure that a coordinated and effective Federal Government advanced ceramics R & D program continues in the ensuing years.

64-850 0 86 - 5

APPENDIX A

UNITED STATES
ADVANCED CERAMICS ASSOCIATION
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605 Fourteenth Street, NW
Washington, DC 20005
Telephone 202 638-1200
Telex 756546

UNITED STATES ADVANCED CERAMICS ASSOCIATION
MEMBERSHIP LIST
SEPTEMBER 1986

Adolph Coors Company/Coors Porcelain
Advanced Refractory Technologies, Inc.
Aluminum Company of America
Blasch Precision Ceramics, Inc.
Celanese Corporation *
Ceradyne *
Champion Spark Plug Company
Chrysler Corporation
Corhart Refractories, Inc.
Corning Glass Works
Dow Chemical Company
Dow Corning Corporation
E.I. du Pont de Nemours & Company
Electro-Science Laboratories, Inc. *
Engelhard Corporation *
Ferro Corporation
Garrett Corporation
General Ceramics, Inc.
General Motors Corporation
GTE Products Corporation
Lanxide Corporation
Martin Marietta Corporation
McDanel Refractory Company
Norton Company
PPG Industries *
Standard Oil Engineered Materials Company
Sundstrand Corporation *
The Titan Corporation
Union Carbide Corporation
W.R. Grace & Company

* Applied for membership.

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APPENDIX B

GOAL AND OBJECTIVES OF USACA

Promote the commercialization of the United States advanced ceramics industry.

- Gather and disseminate worldwide information relating to the advanced ceramic industry.

- Educate policymakers and the general public on the definition, economic advantages, uses, and applications of advanced ceramic structures.
  - Outreach through annual conferences.
  - Develop a trade show booth to promote advanced ceramics.
  - Sponsor user-oriented design seminars.
  - Develop public relations programs in support of the U. S. Advanced Ceramic Industry.

- Identify aids and barriers to the commercialization of the industry.
  - Study possible cooperative industry-sponsored R & D programs.

- Support and, where appropriate, advocate positions of interest to the USACA membership.
  - Vigorous support for pending legislation to further protect U. S. process patents.
  - Provide testimony in support of continuing DOE sponsored research for ceramics as well as today's testimony.
  - Request that the Department of Commerce establish a technical advisory committee on materials and to establish a unique set of Standard Industrial Classification codes so that the U. S. advanced ceramic industry can be quantified and viewed as a distinct entity.

- Study and develop recommendations regarding standards or targets for the industry.

APPENDIX C

INTERNATIONAL ACTIVITIES IN ADVANCED CERAMICS

Japan

The Japanese long-term industrial strategy revolves around the development and commercialization of emerging technologies such as advanced ceramics. These high potential, high risk opportunities are targeted early by MITI (Ministry of International Trade and Industry) for special emphasis and support. The combined commitment of government and industry have made this strategy successful in the past. Market forces, such as the need for ceramic materials to support other high-tech industries, has led to continued interest on the part of the Japanese industry. The government's involvement stems from the recognized potential of advanced ceramics to alleviate many of Japan's energy and material problems and to provide technical support to other emerging industries.

Heat engine activities in Japan now appear to have reached the same point as the U. S. and West German programs in realizing that advanced ceramics require more research and development before broad commercialization can be realized[1]. The stated problems identified in Japan are universal and not unique. To address these issues the Japanese are now establishing a national basic materials R & D progam similar to DOE's Ceramic Technology for Advanced Heat Engines (CTAHE) program. However, only in Japan is the commercialization of automotive engine components taking place with successes at Nissan (turbocharger rotors), Isuzu, and Mazda (pre-combustion chambers). Other component introductions (rocker arm inserts) appear to be on the horizon. The Japanese forecasted timetable for broad based engine related commercialization is now stated to be the 1990s, consistent with earlier U. S. forecasts.

Current estimates put Japan's share of the world market of advanced ceramics at 50 percent. There is effort underway in Japan to maintain market dominance through educational assistance, technical support to the industry, and a combined industry/government financial commitment of $150-300 million per year.

West Germany

A nine-year national R&D program to develop and commercialize advanced ceramics was initiated in West Germany in 1974. A total budget of $33 million was supported equally by government and industry. Recently, a new ten-year program to develop advanced materials, including ceramics, was begun. The budget for the new program is $23 million per year and is also supported by industry and government.

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1 Wall Street Journal - August 22, 1986

Sweden

Second to Germany, Sweden is the most active European country in advanced ceramic development for engine applications. Approximately 14 companies, the government and several universities are involved in a national cooperative effort begun in 1976. Many of the USACA members are involved in a cooperative effort with Sweden and Germany on ceramic testing and characterization standardization through a DOE International Energy Agency Agreement.

United Kingdom

In the early 1960s, the United Kingdom began development of advanced ceramics for engine applications. Technologically, the program was successful, but it was discontinued due to poor market prospects at that time. Currently, there is a renewed commitment on the part of the government and industry to pursue advanced ceramics technologies and to regain an internationally competitive position. Two consortiums have been formed to increase R & D efforts for heat engines. These programs have received government approval, but funding levels are uncertain at this time.

France and Italy

Other nations, such as France and Italy, are providing funds to several industries involved in ceramics development.

Iron Curtain Countries

Little is known of the activities in advanced ceramics that are occurring in iron curtain countries. However, improved knowledge of those activities would be of great interest to both the U. S. government and industry.

SLIDES TO BE USED IN AN ORAL PRESENTATION

BY

JONATHAN W. HINTON

ON BEHALF OF

THE U. S. ADVANCED CERAMICS ASSOCIATION

USACA

Promote the commercialization of the United States advanced ceramic industry.

USACA MEMBER COMPANIES

Adolph Coors Company/Coors Porcelain
Advanced Refractory Technologies, Inc.
Aluminum Company of America
Blasch Precision Ceramics, Inc.
Celanese Corporation
Ceradyne Corporation
Champion Spark Plug Company
Chrysler Corporation
Corhart Refractories, Inc.
Corning Glass Works
Dow Chemical Company
Dow Corning Corporation
E.I. du Pont de Nemours & Company
Electro-Science Laboratories, Inc.
Engelhard Corporation
Ferro Corporation
Garrett Corporation
General Ceramics, Inc.
General Motors Corporation
GTE Products Corporation
Lanxide Corporation
Martin Marietta Corporation
McDanel Refractory Company
Norton Company
PPG Industries
Standard Oil Engineered Materials Company
Sundstrand Corporation
The Titan Corporation
Union Carbide Corporation
W.R. Grace & Company

TODAY'S COMMERCIAL PRODUCTS

CHEMICAL PROCESS INDUSTRY
- Mechanical Seals
- Nozzles
- Valve Components

AUTOMOTIVE
- Electronic Controls
- Catalytic Converter Substrates
- Spark Ignition Components
- Exhaust Gas Sensors

OIL INDUSTRY
- Flow Control Valves
- Blast Sleeves
- Bearings

ENVIRONMENTAL
- Waste Water Treatment Filters
- Flue Gas Desulphurization Components

METALS PROCESSING
- Burners
- Kiln Components
- Cutting Tools
- Molten Metal Filters

DEFENSE
- Ceramic Armor
- Submarine Shaft Seals
- Rocket Nozzle

ELECTRONICS
- Semiconductor Packages
- Multilayer Capacitors
- Pressure and Gas Sensors
- Optical Wave Guides

TODAY'S PROTOTYPE APPLICATIONS

- Chemical Process Heat Exchangers
- Recuperators for High Temperature Processing Furnaces
- High Performance Electronic Components
- Automotive Valve Train, Combustion Zone and Turbocharger Components

FUTURE APPLICATIONS

AUTOMOTIVE
- New Engine Designs
  - turbine
  - low heat rejection diesel
  - rotary

BIOCERAMICS
- Artificial teeth, bones, heart valves

AEROSPACE
- National Aerospace Plane
- High Temperature, Low Weight Engine Components
- Advanced Electronics
- Fuel Cells

CHEMICAL PROCESSES
- Advanced Composite Systems

ELECTRONICS
- Advanced Multilayer Semi-conductor Packages

DEFENSE
- SDI
- Advanced Armor
- Defense Aerospace Applications
- Advanced Battle Tank Power Trains

U.S. ADVANCED CERAMIC MARKET
$ Billions

MARKET STUDY (DATE)	1980	1985	1990	1995	2000	2005	2010
H.K. Bowen, MIT (1982)	1.5	-	5.0	7.0	-		
U.S. Dept. of Commerce (1984)	0.6	-	2.5	-	5.9		
Charles River Assoc.	-	-	5.0	-	15.6		
Chemical Hitech (1985)	1.0	1.3	6.0	11.0	20.0		
Business Communications Company (1985)	-	1.8	4.6	10.0	18.6		
Teotia & Johnson (1985)* (Argonne Nat'l. Lab)	-	2.1	3.0	3.7	4.5	5.6	
Find SVP (1985)	-	1.4	-	-	-	-	17.9
Stanford Research Institute (SRI)**	-	0.2	-	0.5	-	-	-
Frost & Sullivan (1985)	-	2.9	4.5	-	-	-	-

* Heat Engine Only
**Structural Only

Ceramic Bulletin, Vol. 65, No. 1 (1986) compiled by Greg Fisher (ACerS)

INTERNATIONAL ACTIVITIES

JAPAN

WEST GERMANY

SWEDEN

UNITED KINGDOM

FRANCE/ITALY

IRON CURTAIN COUNTRIES

THE U.S. INDUSTRY RESPONSE

- Resource Investments
- New Entrants into the Market
- Joint Ventures/Acquisitions
- Formation of USACA

WHY FEDERAL GOVERNMENT INVOLVEMENT IS NEEDED

- A Compelling National Interest
  - advanced ceramics are non-critical materials
  - energy conservation
  - international competitivenes

- Proof-Of-Concept For New Ceramic Applications
  - new materials and new engineering designs
  - infrastructural changes for new applications
  - Advanced ceramics must be viewed as structures rather than just materials.

THE NATIONAL CRITICAL MATERIALS COUNCIL

- Advise the President and other key government officials regarding the importance of advanced ceramics.
- Assist in the formulation of Executive Branch policies.
- Identify areas of needed research.
- Identify and inform U.S. industry of advanced ceramic activities in Iron Curtain countries.
- Identify overlap and unnecessary duplication of efforts.
- Maintain a centralized database of ongoing activities.
- Consult with the advanced ceramics industry.

NEED FOR ADDITIONAL ADVANCED CERAMIC FEDERAL GOVERNMENT R & D

- The past and present Federal government R & D expenditures for Advanced Ceramics have been successful.

- The U.S. is at the threshold of developing a healthy and stable advanced ceramic industry able to compete in worldwide markets.

- There still remains several key areas where Federal Government R & D is needed.
  - Basic Research
  - New Materials & Structures
  - New Systems

- Advanced ceramics offer tremendous advantages over other materials in certain applications and their future development is strategically critical to the advanced material needs of the U.S.

- Establish "Proof-of-Concept" for advanced applications.

ADVANCED CERAMICS IN JAPAN

STRATEGY

- Commercialize Emerging Technologies
- MITI Emphasis and Support

PROBLEM

- Need for Increased R & D

SUCCESSES

- Heat Engines
  - Nissan
  - Isuzu
  - Mazda
- Electronics
- Overall World Market Share 50%

USACA GOVERNMENT AFFAIRS COMMITTEE

OBJECTIVES

- EDUCATE
- ADVOCATE

GOAL AND OBJECTIVES OF USACA

Promote the commercialization of the United States advanced ceramics industry.

- Gather and disseminate worldwide information relating to the advanced ceramic industry.
- Educate policymakers and the general public on the definition, economic advantages, uses, and applications of advanced ceramic structures.
- Identify aids and barriers to the commercialization of the industry.
- Support and, where appropriate, advocate positions of interest to the USACA membership.
- Study and develop recommendations regarding standards or targets for the industry.

Mr. BROWN. Thank you very much, Dr. Hinton.

Let me ask both Dr. Ford and Dr. Hinton, first, whether there has been any formal contact with the Critical Materials Council with regard to developing a program of cooperation between each of your organizations and the Council.

Dr. FORD. For FMS, the direct answer to that is no, but it should be softened somewhat in that we have had considerable informal contact with Brien Benson as Executive Director of the Council and have repeatedly offered to assist him. We are eager to do that. We feel that that is a classic example of the role of FMS in acting as a conduit between the materials community and the Federal Government.

Mr. BROWN. Dr. Hinton.

Dr. HINTON. USACA has had some preliminary discussions with Mr. Benson and, as FMS, have offered our support, assistance, and cooperation and I believe are starting to establish an ongoing dialogue of things to discuss, but it is in the very formative stages at the present time.

Mr. BROWN. I want to set forth my perception of a problem here, and that is that this administration, probably rightly, at least sincerely, is concerned about an appropriate relationship between the Federal Government and private industry in any matters of this sort. We think there is an appropriate relationship. I think you gentlemen share that view, but defining it is sometimes difficult, and we think that there may be a need to assist appropriate members of this administration in understanding what is an acceptable, helpful, beneficial relationship between Government and private industry.

The Congress is not trying to force any concept of centralized planning on the administration or anything of that sort, but we do perceive—and I think we've been trying to keep abreast of these kinds of changes now for a number of years—that there is a changing atmosphere that requires closer cooperation between industry and Government, and that's the concept that we'd like to have your help with in working with appropriate members of the Federal Government.

I don't want to over-stress that point, but ultimately we've got to have a coherent national strategy that will allow us to keep up with competition in the rest of the world.

Now can I ask you gentlemen to lend your efforts to that sort of an educational program?

Dr. HINTON. Yes, Mr. Chairman. That's absolutely the goal of USACA. The reason that 30 companies to date and I'm sure many more have joined forces in this effort is the recognition that—to quote a phrase—some of our offshore competitors will eat our lunch if we don't do the right things now to coordinate a national materials policy, and therefore we would certainly extend the assistance of our executive director, his staff, our Government Affairs Committee which I chair, to assist in any way we can with the information and education about what the key issues really are that we think need to be addressed.

Dr. FORD. For FMS, I reiterate what I said before. Of course we want very much to provide that role.

I would add as an individual, as an industrialist, that my belief is that industry is anxious to develop a cooperative approach with the Federal Government rather than an antagonistic, which has been perhaps the history of the Government-industry relationship and has taken steps with the Government in some areas in the materials community to do that. I give you examples of the assessments of the materials in the national stockpile that have been conducted through ASM and NMAB by voluntary use of industrial people, and we are anxious to do that. It's critical to the strength of the materials community.

Mr. BROWN. May I inquire as to whether your organizations participated in a consultative way in the development of the OTA report on this subject? Were you invited to offer comments or participate in any other way?

Dr. HINTON. I can't speak for all the USACA member companies, but I know of at least five, my own included, that participated in the collaborative discussions, and I will have to ask my executive director behind us here whether USACA themselves participated.

We were too young, and it was too far along, he says.

Mr. BROWN. Yes.

Dr. FORD. FMS has been aware of and cognitive of the work in the assessment and has had reports and input to the work.

Mr. BROWN. All right. I want to give Mr. Coppola an opportunity for some input here. I've just looked at a Wall Street Journal article which suggests that Japan is losing some of its interest in ceramics, and I presume advanced ceramics, reflecting certain problems, according to the article, that developed in pursuing this field. Could you cast a little more light on this based on your own experience in Japan, Mr. Coppola?

Mr. COPPOLA. Mr. Brown, I found that personally a very interesting article in terms of reading the content, and I think the title is somewhat misleading in its message, but basically our perception is that it appears that the Japanese have now reached a point where——

Mr. BROWN. Three bells.

Mr. COPPOLA [continuing.] Where they've reached the same point that the United States and the West German advanced ceramic programs have reached, in realizing that considerably more development is required before a broader based commercialization can take place. The stated problems that they identify, just as joining or brittleness and cost, are not unique and very much universal.

From conversations I've had with people in the industry in Japan, they have established a more basic R&D program to address some of these issues very similar to what the Department of Energy has done in terms of the ceramic advanced gas turbine, advanced heat engine programs.

I think the fact does remain, though, that only in Japan are you seeing this commercialization take place in terms of automotive components, such as, as was said earlier, the Nissan turbocharger activity, the components in the Isuzu and Mazda engines, and we still forecast an ongoing effort there with additional components coming on the horizon. And I think, in conclusion, on that article, based on their statements in terms of the—their forecasted broad-

based commercialization, is very consistent with what we've been saying for the last 4 or 5 years, and that is the 1990's.

Mr. BROWN. Without objection, I'd like to insert that article in the record so that we may put your comments in context with that.

[The Wall Street Journal article follows:]

Ceramic Engines Losing Support in Japan

By Stephen Kreider Yoder
Staff Reporter of The Wall Street Journal

TOYOTA CITY, Japan—In a back room here at Toyota Motor Corp.'s headquarters, a ceramic engine has been gathering dust for four years.

Toyota built the engine in the early 1980s, when the automotive world thought ceramics would soon replace steel inside car motors. The notion caught the fancy of car enthusiasts around the world, and the news media widely predicted a ceramics revolution that would produce powerful yet fuel-sipping engines that wouldn't need radiators.

But Toyota found that ceramic engines didn't live up to expectations. "We studied them for a long time," says Ryono Ito, general manager of Toyota's technical-planning office. "But we weren't able to get favorable results." So Toyota, Japan's largest auto company, abandoned its ceramic-engine program.

After several years of research, auto makers here are sharply divided on the future of ceramics in engines. A few, notably Isuru Motors Ltd., still argue that ceramic engines are just around the corner. Most makers already use ceramics for specialized engine parts. But Japan's biggest auto companies say they don't expect to see ceramic engines widely used in cars before the next century, if ever. Ceramic engines have proved expensive, fragile and inefficient. And some makers even question the theories that led to research in the first place.

The idea of a ceramic engine "was mostly an illusion," says Takane Ito, a Nissan Motor Co. engineer. "Everyone made a lot of noise about it without doing their homework . . . . But there aren't any simple solutions lying around. Whichever way we turn, there are only bottlenecks."

Makers such as Toyota and Nissan haven't given up on ceramics entirely. But they have retrenched to look for less-sweeping but more-practical applications for ceramics outside engines, in parts such as seals and turbocharger blades.

Ceramic parts for engines were supposed to do amazing things. Using the material to line cylinders and cap pistons, engineers expected to design engines that wouldn't need cooling systems and would cut energy consumption and raise power. ("Ceramic engine" is a misnomer, because only certain internal parts would be ceramic. The rest of the engine and the housing would be steel or aluminum.)

The dream was to create an engine that didn't waste energy in the form of heat. A conventional engine running at 390 degrees Fahrenheit loses more than one-third of its energy in the heat that goes to the radiator. But by insulating an engine with a material that can withstand temperatures in excess of 1,800 degrees, so the theory goes, energy normally lost in a conventional engine would be redirected as extra horsepower.

Engineering ceramics withstand temperatures that quickly turn metal into goo. As a bonus, some ceramics are more "slippery" than metal, allowing the theoretical engine to run without oil. And with no radiator to build around, car designers expected to be able to create currently unthinkable body styles.

The idea for a ceramic engine surfaced when the U.S. Army sought to camouflage military trucks from heat-seeking missiles. The army wanted a truck without a radiator, and Cummins Engine Co. of the U.S. began research in 1971 that resulted in a ceramic engine three years later.

The Cummins engine never went into production, but the Japanese picked up on the idea and began the push to commercialize it in the early 1980s, when the engines seemed attractive because of their fuel savings. Ceramics makers did all they could to encourage them. Says Mazda Motor Corp. engineer Jun Miyata: "The ceramics makers were waving the flag harder than anyone."

But while some companies continue to sing the praises of ceramic engines, many auto and ceramics makers have become decidely low-key about their projects. "It's been very hard to admit that it doesn't work," says Toyota's Mr. Ito.

Ceramics simply haven't cooperated. Some types are good insulators. Others stay tough at high temperatures. In the early 1980s, engineers expected breakthroughs that would lead to ceramics that did both. It hasn't happened. "One of the biggest problems today," says Roy Kamo, who started the Cummins project but has since left the company, is that "you don't have materials that will do the job."

Today's ceramics won't stick well to aluminum and steel and are about 100 times more brittle than steel. And the materials are prohibitively expensive.

What's more, the quality of identical parts varies widely; defect rates are as high as 50%. "The reliability level is completely unacceptable for mass production," says Nissan's Mr. Ito.

But the biggest problems are even more fundamental. Engineers found early on that high temperatures make the engines knock, and cause incoming air to expand so much that the engine can't draw in enough oxygen to burn fuel correctly. To make matters worse, Nissan's and Toyota's experimental ceramic engines put out more pollutants, in some cases as much as 25% more. "We've run aground," says Nissan's Mr. Ito. "It's a deadlock both in hardware and in theory."

Falling oil prices also have helped damp ceramic-engine programs. "The pressure to save on fuel efficiency isn't there right now to balance the huge capital investment on a very expensive vehicle," says Francis Moyer, a securities analyst in Tokyo with W.I. Carr, Sons & Co.

Isuru engineers think otherwise. The company has five experimental ceramic engines ranging from 1.8 to 9.8 liters and has run them a total of 3,500 hours "without any problem," says Hideo Kawamura, the engine-development manager. Isuru expects to put ceramic engines in production cars in the 1990s.

Despite their optimism, though, Isuru engineers concede they need some breakthroughs to find the ideal ceramic at a cheap price.

Ironically, ceramics may have the best chance in the rotary engine. Mazda, the only company in the world still building the engine, which uses triangular rotors instead of pistons, says the gasoline-powered rotary is immune to many of the problems encountered by piston-engine versions of ceramic engines. Early this year Mazda ran its first ceramic prototype for 22 hours without problems.

Company engineers give the 1990s as a possible commercialization time. "But whether it has cost-efficiency merits, we don't know yet," adds Mazda's Mr. Miyata.

Mr. BROWN. Mr. Lewis, do you have any questions?

Mr. LEWIS. Mr. Chairman, I have just three questions I'd like to ask of the panel as a whole.

Do you have any confidence or any great optimism that the Materials Council will succeed in solving some of the problems facing the materials community today? If you feel like that's a loaded question, you don't have to answer it.

Dr. FORD. That's a loaded question. But being an optimist and seeing now the appointment of Mr. Hodel who is supportive, in my experience, he certainly was supportive of the Mott Committee and receptive to recommendations that the Mott Committee made, although very little was done beyond that. Mr. Hodel is, I think, sensitive to, and understanding of, the materials community needs and the national needs in relation to materials, and therefore I will begin anew with optimism.

Dr. HINTON. We would certainly share that optimism. We'll look forward to Mr. Hodel coming onboard and seeing Mr. Benson fill some of those 12 spots that are available there, I believe, and, again, offer our support and hope that as they move forward we'll be able to participate and work with them, and I think that we'll be watching their activities perhaps just as closely as you, Congressman.

Mr. LEWIS. Mr. Coppola, do you feel the same way?

Mr. COPPOLA. I feel the same way, sir.

Mr. LEWIS. You won't get in trouble with that statement.

If you had one piece of advice to offer to Dr. Moore in respect to the Materials Council, what would it be? Or do you feel that that's not in your responsibility? In other words, for the Materials Council to progress. You just did, Mr. Hinton, state about maybe filling the other 12 positions, but is there something we can do? We've been waiting for a report for a long time, and the report was due over a year ago—April a year ago, and we certainly haven't received the report. Do you have any suggestions or advice?

If you don't feel like you want to answer that, gentlemen, you don't have to.

Dr. HINTON. I have nothing concrete that I would want to offer, I don't think, at this time, Mr. Lewis.

Dr. FORD. It may perhaps sound presumptive, but we, FMS, think we do have some things to offer and have offered them in the past. We will continue to offer them.

Number one, Mr. Moore indicated that he was just learning about this materials field. We have the materials community behind us as a resource. We can offer him the experts needed so he can understand the needs and requirements of the materials field. We offer that; we eagerly offer that. That is a step that can be taken right away.

Mr. LEWIS. Has that been offered in the past, Dr. Ford?

Mr. FORD. Yes, sir, that has, and they are, as I mentioned, in an informal way in this learning period, I'm sure, using the expertise we give to them.

We have met with them a number of times, but we are also anxious to see greater progress and a greater sense of urgency, and that could be assisted if milestones, to use your words, were established, and goals, and timetables, and schedules were established

with critical points and critical needs so that we could help them staff their effort through the voluntary method.

Mr. COPPOLA. I concur with the comments of FMS, and in more of a personal situation what I'm going to be doing with Brien Benson in the near future is giving him as complete a debriefing on my activities in the situation in Japan and to give him a broader base inside as to how the Japanese are pursuing in this area as much as I know. So that's an area that we've offered and we're going to follow up on.

Mr. LEWIS. I have an easier one for the panel. What advice would you give to Congress or this subcommittee so that we might be able to help the Council? I think we've tried to provide them, as the chairman has pointed out, the funding as well as the positions. Are there any additional things that we could do?

Dr. FORD. Continue the heat.

Mr. BROWN. Mr. Lewis, would you yield for a moment?

Mr. LEWIS. I certainly would yield.

Mr. BROWN. While you were out, I suggested that since this panel represents a very distinguished group of companies in the private sector, many of which companies have very strong ties with the administration, that perhaps some of this resource could be used to help educate policymakers in the administration to the urgency of this. I don't feel yet that the message has completely gotten through the Executive Office.

I don't want to force the Executive Office into a program they don't want, it's counterproductive to try and to do that, but I think that we could seek, in various ways, to make them aware of the urgency of this problem and hope that they would respond through a different treatment of the Council and its role.

Mr. LEWIS. Dr. Hinton.

Dr. HINTON. Let me just comment that I think perhaps holding a hearing like this, and hopefully future ones as well, certainly serves a very useful purpose in what I think you and ourselves and the Critical Materials Council are headed toward.

You have to recognize that the ceramic community as a whole, perhaps, was fairly fragmented prior to the formation of USACA. It evolved as a lot of smaller companies. Now that there has been considerable joint venture and acquisition, bigger companies are now involved in and developing advanced ceramic programs, and those bigger companies have more of a feel for how you educate and inform here in Washington. I think there'll be more of an opportunity for you to hear of our views than what you would have had from the smaller, more fragmented ceramic community.

So I think the continued opportunity to provide interchange of this type would be one of my strong recommendations, in answer to your question, Congressman Lewis.

Dr. FORD. I'd reinforce the education part of Congressman Brown's comments. Not only does the administration not have a sense of the urgency and value of materials to our economy but the general public doesn't either. Materials are the most taken for granted thing that we have. We would have nothing of our present standard of living without a very strong, growing materials economy—materials understanding, and the general public does not know and understand that, so that people like yourselves, our Rep-

resentatives, are not made aware throughout our Government of the need for a materials policy; it's just something that we all take for granted.

Mr. COPPOLA. I would certainly add to those comments in the sense that if you look at why has Japan been successful, one of the reasons, especially in terms of the ceramic activity, is that they have gone out of their way in educating the public. The average individual has a much broader understanding of ceramics and materials and how they contribute to the economy than we have here. So obviously education is a key element of the beginning of a program, in my mind.

Mr. LEWIS. Mr. Chairman, I certainly do not want to be hostile toward the Council, as you. I'm very pleased that we now have Secretary Hodel as the Chairman, and Mr. Martin as Deputy Secretary for Energy is a new appointee along with Dr. Moore, who I think is eminently qualified for this Council, and certainly not taking anything from Mr. Benson; I think that his job is certainly one of gathering information, getting it together. But, as I mentioned earlier, I will be visiting with them and seeing if we can't move on, because to me this is a very important situation that certainly should not be shoved under the table, and to feel that we have to wait over a year and a half for a report that was due April a year ago certainly is unbelievable, particularly with the world situation in materials and metals as it is, and I certainly will continue to pursue our initiatives in this area, and I thank you, Mr. Chairman, for holding this hearing, I think it's been very informative.

Mr. BROWN. Mr. Packard.

Mr. PACKARD. Thank you, Mr. Chairman.

One of the geniuses, I believe, of the free world, and particularly the United States, being able to remain on the cutting edge of technology in these materials areas is the dual role or the dual effort that we have going on in this country, the Government effort as well as the private sector effort, and I think you have recognized from my own questions that I'm concerned about the articulation of these two efforts and the sharing of information.

In your judgment, from the private sector's viewpoint, are we correlating our efforts in Government research versus private sector research, and are we communicating well enough to where we share the information that is achieved in our research programs to where we get the maximum advantage in terms of a marketable product?

Dr. Hinton.

Dr. HINTON. Let me just comment on that, Congressman Packard. I think the technology transfer is a big piece of what your question focuses itself on, and that is, can we get the technology once it's developed out of the Government labs and make useful products from it?

Certainly there have been considerable strides and improvements made in that in recent years, and I personally and my company can see that the opportunity to interchange with particularly the folks at Oak Ridge National Laboratories or NASA, places like that, has considerably improved, and we do have better access now than what we had previously.

As far as from your perspective, how are the Federal Government R&D activities coordinated among themselves? I think that's less clear to me, and maybe it's just my remote location in Niagara Falls, NY, that makes it difficult to ascertain that, but I think that might be one thing that the Critical Materials Council could help to ensure, is that there is a focus, that there is an action plan with timetables, there's some knowledge of what might come out of these activities, and make sure that there is no unnecessary duplication and overlap.

Mr. PACKARD. Does the international sector have access, equal access, to information? Should they, and, if they do have more access than you feel they should, is that impeding our own competitive ability to compete?

Dr. Ford.

Dr. FORD. Well, that's a difficult question to answer. As a member of the defense contractor community, my private role, I feel very strongly that there is a great need to protect national security information but that we also see perhaps a bit of hiding behind that veil to prevent discussions of topics that are so basic that we might learn more than we would teach if we could have open discussions, for instance, in the composites.

The composites area, if I understand the rules and regulations right now, almost all advanced composites information that is generated within our Government's sponsorship here is considered national security limited, and so there is a tremendous wall or barrier to exchange of information and—is that a three-bell, too?

Mr. BROWN. One long bell.

Mr. PACKARD. Then probably two short ones later.

Dr. FORD. And that barrier may lead to us losing more from learning, the learning side, than we would give in the teaching, and so I think it's a difficult question to answer quantitatively. We must protect those true security areas of information, and I see a great deal of it given away in my business, things that come through the public press that amaze me, but there's a lot of places where we hide behind the veil of security.

Mr. PACKARD. It appears to me that we follow a rather well-defined and well-practiced pattern in our international competitiveness in respect to technology. We are again, I think, leaders in developing technology and seeing its potential, and we exploit it and use it for our commercial benefit, but relatively in a short time that information is obviously available to competitors, international competitors, and they find ways, cheaper ways and faster ways, of mass producing it, and then that industry tends to die out to some degree here in this country. The textile industry is a good illustration. We find now where it's very difficult for our industry to compete internationally. The steel industry is another illustration.

Do you see down the road, another 10 years, a decade or more, or less, where the composites will be—of course, where we're on the leading edge—will be taken over and then we have to look to new technology to keep our industries viable and competitive, recognizing that this will become an older industry and therefore will be taken over in the international sector? Is that a cycle we're going to have to become complacent with and accept, or are there ways

that we can extend the life of the industry, the preeminence in the industry in our own country?

Dr. FORD. I think we'd better do the latter, or we're in trouble. The present philosophy, Federal philosophy, especially in the administration, has been, "Don't worry about the smokestack industries; they're gone; we don't need them any more because we have this high-technology industry coming along to support us and provide the growth and the new jobs," and I commented in my testimony, although it's not in the written testimony, clearly the electronic materials falls in the new high-technology regime; it is the basis for the communications system and growth—a high-growth industry, and clearly that industry is now well into the steel syndrome.

I mentioned the silicon for rectifiers. It's totally offshore. Most of our silicon industry is offshore. The marketplace has gone from a United States market to a Japanese market, and the reason it's gone there is not because of innovation or inventiveness—excuse me—it is because we are not capable of completing the innovations cycle which is to go to commerce with a cost-effective product. The other countries are beating us in that game. We are doing the basic research, but we are not doing the job of transferring that basic invention to commerce.

Mr. PACKARD. I appreciate those comments. I appreciate the entire hearing, Mr. Chairman. I think if a message is coming out of it, it certainly is that we need to do a better job of assisting the private sector and, of course, the research community, both Federal Government and private research community, of articulating and communicating and exchanging information to the extent that we get more out of the research that's being done in this country. It's an area that I think we've been discussing at length, and certainly the chairman is aware of that—he's participated—in our Science Policy Committee meetings, and now that we're drafting up a national science policy, I hope that we will be able to include in that some goals and objectives and perhaps some techniques of reaching those goals and objectives of better transferring our research and our ability to remain on the cutting edge of developing very significant research, converting that into marketable products and assisting the private sector of doing just that. I think it's key to our own economic long-term salvation.

Thank you, Mr. Chairman, for the hearing.

Mr. BROWN. The gentleman's remarks are very perceptive, and of course the phenomenon we are discussing here is not unique to the critical materials or advanced ceramics situation.

You have indicated that this field is one of three high-priority fields, the other two being biotechnology and what you might call the general field of the information sciences. This field has received far less attention than the other two.

We are doing a better job in getting our act together, for example, in biotechnology, still far from perfect, and in the information sciences, which is complex and pervasive, we are not doing very well, and in this area we're not doing very well at all. But the policy issues run across all of these areas and require the most sensitive and enlightened cooperation between private industry and Government in coordinating our efforts.

I really am appreciative of the contribution you gentlemen have made to our better understanding of what needs to be done here, and we're gradually groping our way toward the kind of policies which I think will assist us here.

Let me explore just momentarily another issue. One or the other of you made some comments about the proposed ceramic advanced manufacturing development—Dr. Hinton—developing an engineering center, and all of you have focused on the need to integrate our concern with the research on advanced ceramics or other new technologies with the manufacturing process, which of course is extremely important.

I'd like to ask you to comment a little bit more on this proposed center, whether you have in mind some model as to how it should be organized and supported and the scope or general nature of the resources that would be required to do a good job here.

We have some prototypes. The NSF is supporting National Engineering Research Centers in a number of different areas, a very constructive program, in my view, for which the administration should be commended, except the level of resources devoted to it and the breadth of the program is not yet adequate to the problem. I wonder, Dr. Hinton, if you could elaborate a little bit more on the possibilities in this kind of an organization.

Dr. HINTON. Congressman, I would certainly support your statement that precious little is being spent or the program is not sufficient in scope at the present time. I would like to respectfully request, however, that maybe I could submit for the record some comments on this CAMDEC after next week. The initial meeting of the advisory committee, of which I will be a member with five of my colleagues from industry, will be going to Oak Ridge to talk about this center on the 24th of September, and at that point in time we're going to discuss the issues that would probably be of interest to you—the funding, the organizational structure, and what do we think we're willing to do to make it effective, and how will we get industry to participate. If I could submit to you perhaps some written comments after my visit there next week, that would be perhaps more appropriate from my viewpoint.

Mr. BROWN. That would be satisfactory as far as we're concerned. I think that proposals of this sort are well within the existing authority of the Federal Government without further help from Congress, but if such help might be beneficial, I think we're interested in providing whatever assistance might be required.

[The information follows:]

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November 26, 1986

The Honorable George E. Brown, Jr.
Chairman
Subcommittee on Transportation, Aviation
and Materials
Committee on Science and Technology
2321 Rayburn House Office Building
Washington, DC 20515

Dear Chairman Brown:

During my recent testimony relating to your Subcommittee's overview of the National Critical Material Council and advanced materials policy you requested additional information about the Ceramics Advanced Manufacturing Development and Engineering Center (CAMDEC).

As a follow-up to your question I wanted to share with you that CAMDEC is a proposal of the Oak Ridge National Laboratory and the University of Tennessee. The center, as proposed, would provide a "test bed" for innovative manufacturing processes for the production of advanced ceramic components. In conjunction with the formation of the Center, the University of Tennessee would establish an interdisciplinary program to train both undergraduate and graduate students and to provide retraining for engineers in advanced ceramics.

In order to move the concept of CAMDEC forward, representatives from Oak Ridge and the University of Tennessee created an Industry Advisory Council that met on September 24 to discuss the CAMDEC proposal. The council agreed that there were three major issues to be addressed before the proposal could be considered:

1. What scope of work would be bold enough to provide a quantum leap forward in ceramic manufacturing technology?

2. What organizational structure would best meet industrial needs and, at the same time, ensure a "partnership" between the private and public sectors?

3. What leverage would CAMDEC provide that would make this high-risk investment attractive in the competition for corporate R&D funds?

(please turn)

Oak Ridge and the University of Tennessee are now in the process of incorporating these issues in a revised proposal that will be prepared by early 1987 and presented to the USACA membership.

USACA will be pleased to keep you and your staff advised of the progress of CAMDEC or other R&D opportunities as they proceed.

Sincerely,

Jonathan W. Hinton
Chairman
Government Affairs Committee

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Dr. HINTON. Mr. Chairman, I should also perhaps mention that you USACA is also looking at this issue itself either in collaboration with or totally separate from Oak Ridge and their desire, and should we find that there is a more appropriate way for us to pursue the development of manufacturing expertise for advanced ceramics, we will certainly try to get some initiative going in that direction.

Mr. BROWN. Well, I want to say a word of commendation for the effort that's gone into the formation of USACA. I think these efforts on the part of diverse industry to pull together around common goals are extremely important, and we have seen models of this—for example, the operation in the computer industry that was set up down in Texas—and, again, the same problems of antitrust barriers or other things needed to be resolved in that connection, if they're needed in your industry, we certainly want to help resolve them.

We've had excellent results in the utility industry when they got together—in the electric utility industry, and I think the gas utility industry has done likewise, to support a joint approach to some of their research problems, and I feel personally that this is part of the pattern which we need to establish with, again, the cooperation of the Federal Government in order to continue our preeminence in these various different fields.

Dr. HINTON. We as an association certainly appreciate the interest and the support we've gotten from you, Mr. Chairman, and the entire subcommittee, and particularly your staff. Dr. Maxwell has been an interested party, an advocate of advanced ceramics, for some time, and we appreciate the opportunity to continue to interface with you, through him, and provide the type of information that you may need to make your decisions.

Mr. BROWN. Fine.

Are there any further questions?

Gentlemen, we are, again, as I said, grateful to you for your participation. We will continue to keep in close touch with you, and if we need additional information, we will ask your cooperation in supplying it in writing.

Dr. FORD. Thank you very much, Mr. Chairman.

Mr. BROWN. Thank you, and the subcommittee will be adjourned.

[Whereupon, at 12:15 p.m., the subcommittee was adjourned.]

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